DOCUMENT RESUME

ED 190 368 SE 031 312

AUTHOR Bonar, John R., Ed.: Hathway, James A., Ed.
TITLE Probing the Natural World, Level III, Student Guide: In Orbit. Intermediate Science Curriculum Study.
INSTITUTION Florida State Univ., Tallahassee. Dept. of Science Education.
SPONS AGENCY National Science Foundation, Washington, D.C.: Office of Education (DHEW), Washington, D.C.
PUB DATE 72
NOTE 125p.: For related documents, see SE 031 300-330, ED 035 559-560, ED 049 032, and ED 052 940. Contains photographs and colored and shaded drawings and print which may not reproduce well.

EDRS PRICE MF01/PC05 Plus Postage.
DESCRIPTORS Astronomy: *Energy: Grade 9: Individualized Instruction: Instructional Materials; Junior High Schools: Laboratory Manuals; *Laboratory Procedures: *Measurement: *Science Activities; Science Course Improvement Projects: Secondary Education; Secondary School Science: *Solar Radiation: Space Sciences
IDENTIFIERS *Intermediate Science Curriculum Study

ABSTRACT

This is the student's text of one unit of the Intermediate Science Curriculum Study (ISCS) for level III students (grade 9). This unit focuses on the properties of sunlight, the use of spectrums and spectroscopes, the heat and energy of the sun, the measurement of astronomical distances, and the size of the sun. Activities are student-centered and intended for individualized instruction. The text is accompanied by illustrations. Excursions are provided as optional activities to allow the students to pursue a topic in greater depth. (SA)

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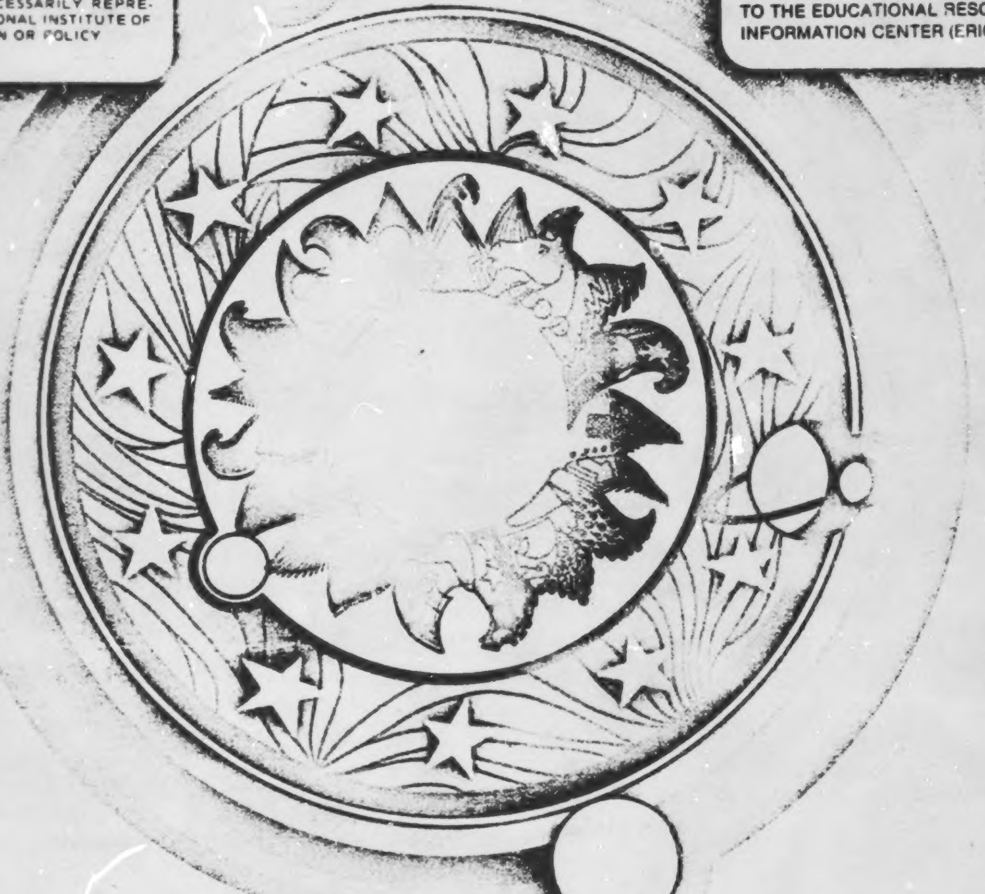

Probing the Natural World/3

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ACKNOWLEDGMENTS

The work presented or reported herein was performed pursuant to a Contract with the U. S. Office of Education, Department of Health, Education, and Welfare. It was supported, also, by the National Science Foundation. However, the opinions expressed herein do not necessarily reflect the position or policy of the U. S. Office of Education or the National Science Foundation, and no official endorsement by either agency should be inferred.

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Foreword

A pupil's experiences between the ages of 11 and 16 probably shape his ultimate view of science and of the natural world. During these years most youngsters become more adept at thinking conceptually. Since concepts are at the heart of science, this is the age at which most students first gain the ability to study science in a really organized way. Here, too, the commitment for or against science as an interest or a vocation is often made.

Paradoxically, the students at this critical age have been the ones least affected by the recent effort to produce new science instructional materials. Despite a number of commendable efforts to improve the situation, the middle years stand today as a comparatively weak link in science education between the rapidly changing elementary curriculum and the recently revitalized high school science courses. This volume and its accompanying materials represent one attempt to provide a sound approach to instruction for this relatively uncharted level.

At the outset the organizers of the ISCS Project decided that it would be shortsighted and unwise to try to fill the gap in middle school science education by simply writing another textbook. We chose instead to challenge some of the most firmly established concepts about how to teach and just what science material can and should be taught to adolescents. The ISCS staff have tended to mistrust what authorities believe about schools, teachers, children, and teaching until we have had the chance to test these assumptions in actual classrooms with real children. As conflicts have arisen, our policy has been to rely more upon what we saw happening in the schools than upon what authorities said could or would happen. It is largely because of this policy that the ISCS materials represent a substantial departure from the norm.

The primary difference between the ISCS program and more conventional approaches is the fact that it allows each student to travel at his own pace, and it permits the scope and sequence of instruction to vary with his interests, abilities, and background. The ISCS writers have systematically tried to give the student more of a role in deciding what he should study next and how soon he should study it. When the materials are used as intended, the ISCS teacher serves more as a "task easer" than a "task master." It is his job to help the student answer the questions that arise from his own study rather than to try to anticipate and package what the student needs to know.

There is nothing radically new in the ISCS approach to instruction. Outstanding teachers from Socrates to Mark Hopkins have stressed the need to personalize education. ISCS has tried to do something more than pay lip service to this goal. ISCS' major contribution has been to design a system whereby an average teacher, operating under normal constraints, in an ordinary classroom with ordinary children, can indeed give maximum attention to each student's progress.

The development of the ISCS material has been a group effort from the outset. It began in 1962, when outstanding educators met to decide what might be done to improve middle-grade science teaching. The recommendations of these conferences were converted into a tentative plan for a set of instructional materials by a small group of Florida State University faculty members. Small-scale writing sessions conducted on the Florida State campus during 1964 and 1965 resulted in pilot curriculum materials that were tested in selected Florida schools during the 1965-66 school year. All this preliminary work was supported by funds generously provided by The Florida State University.

In June of 1966, financial support was provided by the United States Office of Education, and the preliminary effort was formalized into the ISCS Project. Later, the National Science Foundation made several additional grants in support of the ISCS effort.

The first draft of these materials was produced in 1968, during a summer writing conference. The conferees were scientists, science educators, and junior high school teachers drawn from all over the United States. The original materials have been revised three times prior to their publication in this volume. More than 150 writers have contributed to the materials, and more than 180,000 children, in 46 states, have been involved in their field testing.

We sincerely hope that the teachers and students who will use this material will find that the great amount of time, money, and effort that has gone into its development has been worthwhile.

Tallahassee, Florida
February 1972

The Directors
INTERMEDIATE SCIENCE CURRICULUM STUDY

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Notes to the Student

The word *science* means a lot of things. All of the meanings are "right," but none are complete. *Science* is many things and is hard to describe in a few words.

We wrote this book to help you understand what science is and what scientists do. We have chosen to show you these things instead of describing them with words. The book describes a series of things for you to do and think about. We hope that what you do will help you learn a good deal about nature and that you will get a feel for how scientists tackle problems.

How is this book different from other textbooks?

This book is probably not like your other textbooks. To make any sense out of it, you must work with objects and substances. You should do the things described, think about them, and then answer any questions asked. Be sure you answer each question as you come to it.

The questions in the book are very important. They are asked for three reasons:

1. To help you to think through what you see and do.
2. To let you know whether or not you understand what you've done.
3. To give you a record of what you have done so that you can use it for review.

How will your class be organized?

Your science class will probably be quite different from your other classes. This book will let you start work with less help than usual from your teacher. You should begin each day's work where you left off the day before. Any equipment and supplies needed will be waiting for you.

Your teacher will not read to you or tell you the things that you are to learn. Instead, he will help you and your classmates individually.

Try to work ahead on your own. If you have trouble, first try to solve the problem for yourself. Don't ask your teacher for help until you really need it. Do not expect him to give you the answers to the questions in the book. Your teacher will try to help you find where and how you went wrong, but he will not do your work for you.

After a few days, some of your classmates will be ahead of you and others will not be as far along. This is the way the course is supposed to work. Remember, though, that there will be no prizes for finishing first. Work at whatever speed is best for you. *But be sure you understand what you have done before moving on.*

Excursions are mentioned at several places. These special activities are found at the back of the book. You may stop and do any excursion that looks interesting or any that you feel will help you. (Some excursions will help you do some of the activities in this book.) Sometimes, your teacher may ask you to do an excursion.

What am I expected to learn?

During the year, you will work very much as a scientist does. You should learn a lot of worthwhile information. More important, we hope that you will learn how to ask and answer questions about nature. *Keep in mind that learning how to find answers to questions is just as valuable as learning the answers themselves.*

Keep the big picture in mind, too. Each chapter builds on ideas already dealt with. These ideas add up to some of the simple but powerful concepts that are so important in science. If you are given a Student Record Book, do all your writing in it. *Do not write in this book.* Use your Record Book for making graphs, tables, and diagrams, too.

From time to time you may notice that your classmates have not always given the same answers that you did. This is no cause for worry. There are many right answers to some of the questions. And in some cases you may not be able to answer the questions. As a matter of fact, no one knows the answers to some of them. This may seem disappointing to you at first, but you will soon realize that there is much that science does not know. In this course, you will learn some of the things we don't know as well as what is known. Good luck!

The Message of Sunlight

Chapter 1

Space probes have photographed the surface of Mars and of the moon. The Mariner space probes actually sampled the atmosphere of Mars, while the Surveyor space probes sample the soil of the moon. Now men have walked on the moon's surface and brought back rock samples and detailed photographs. It may surprise you to learn that these developments have led to few unexpected results. Most of the information collected supported what astronomers already believed. How did astronomers get such accurate information about objects like the stars, the moon, and the planets without actually going to them? This is the question you will tackle in this unit.

Since you are in school during the day, a good place to start is to study the sun and measure some of its characteristics. Some of the questions about it that you should try to answer include these:

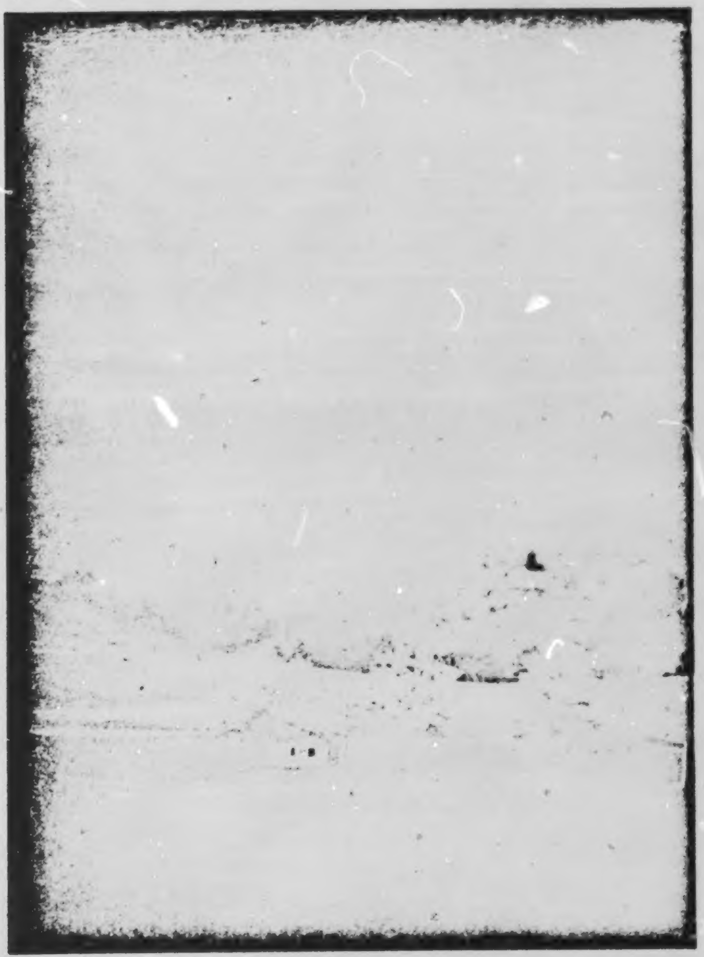
1. What is the sun made of?
2. How much energy does the sun give off?
3. How can the distance to the sun be measured?
4. How large is the sun?
5. How can the motion of the sun be described?

You may think you can answer some of these questions already. Perhaps, for example, you've read somewhere how far it is to the sun. But remember, you should also learn how measurements of the sun are made. Finding out will call for much more thought than simply looking up a number in a book. Once you know how to find such answers, you will be able to investigate celestial objects on your own.

Getting started

Although you may not realize it, the sun is constantly sending you information about itself. Unfortunately, you can't read the information like a newspaper. The information is in the form of light. Figuring out what it tells you about the sun is rather like cracking a code.

One of the ways to read sunlight is to observe how it behaves when it passes through certain materials. You've probably seen an example of this after a rainstorm. Light passing through droplets of rain at a certain angle is broken up into a series of colors. Most people call the result a rainbow. Scientists call it a spectrum.

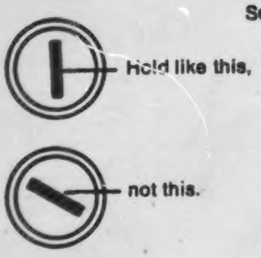


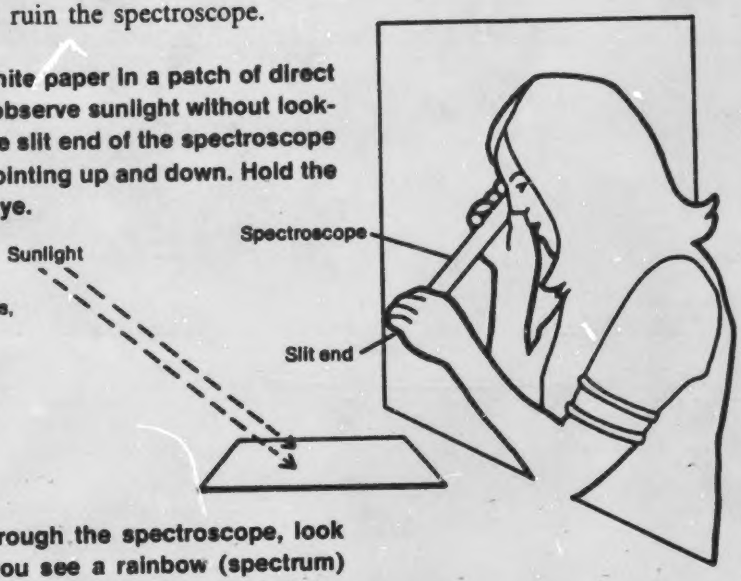
Begin your study of the sun by looking carefully at the spectrum formed when its light passes through a device called a spectroscope. Before you start, however, here is an important warning.

`Safety Note: Never look directly at the sun through any instrument or with your unaided eye. This can cause serious damage to your eyes.`

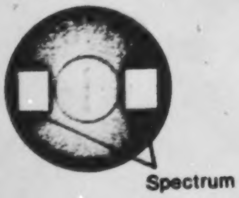
Pick up a spectroscope from the supply area. Be careful not to touch the plastic disk in the eyepiece. The oil from your skin can soil the disk and ruin the spectroscope.

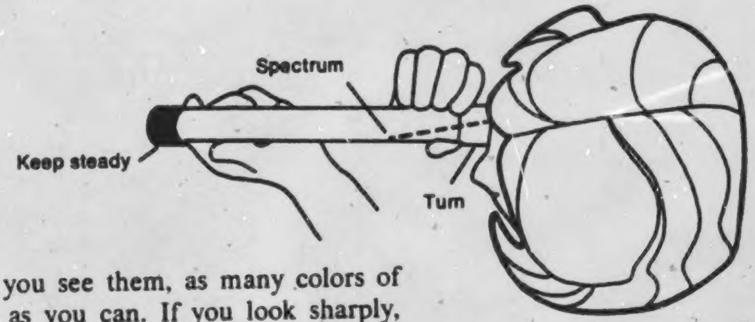
ACTIVITY 1-1. Lay a sheet of white paper in a patch of direct sunlight. (This is a safe way to observe sunlight without looking directly at the sun.) Point the slit end of the spectroscope toward the paper with the slit pointing up and down. Hold the eyepiece snugly against your eye.





ACTIVITY 1-2. As you look through the spectroscope, look to the side of the tube until you see a rainbow (spectrum) clearly. Turn the eyepiece without turning the slit until the spectrum is as wide as you can make it.





☐**1-1.** List, in the order you see them, as many colors of the spectrum of sunlight as you can. If you look sharply, you should be able to see several.

Compare your list of colors with the spectrum photograph in Figure 1-1.

☐**1-2.** How do the number and order of your list of colors compare with those in the photograph (Figure 1-1)?

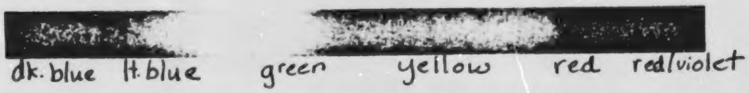
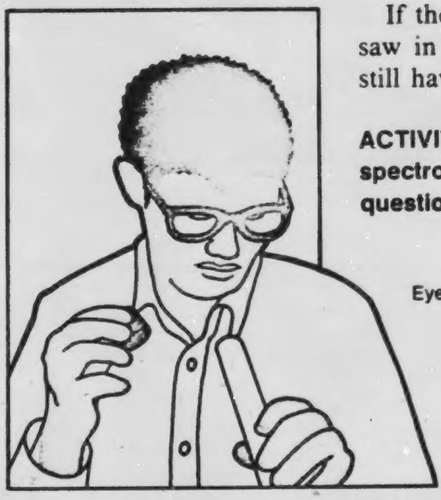
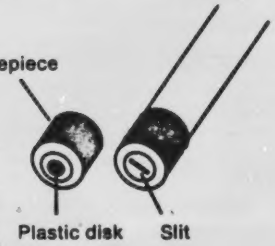


Figure 1-1



If the photograph looks different from the spectrum you saw in the spectroscope, try the experiment again. If you still have trouble, ask your teacher or a classmate for help.

ACTIVITY 1-3. Remove the eyepiece and the slit end from the spectroscope. Experiment with them until you can answer question 1-3.



Note: *Be careful to keep your finger off the plastic disk in the eyepiece*

☐**1-3.** Which causes the spectrum to appear, the plastic disk or the slit? How do you know?

The plastic disk is called a diffraction grating. Thousands of tiny parallel lines have been marked on it. These lines cause the light to spread out into the color spectrum you've seen. This kind of spectrum is called a continuous spectrum because one color continues right into the next.

Using the spectroscope

Earlier, it was said that sunlight carries information about the sun. Now you've seen that sunlight can be spread out into a spectrum. Can the spectrum from sunlight tell you something about the nature of the sun? Is the sun like other sources of light? Perhaps the spectroscope can help you find out.

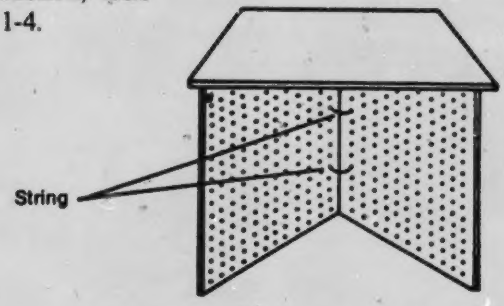
Somewhere in your classroom your teacher has set up a glowing light bulb. Carry your spectroscope to this area and use it to look carefully at the light from the bulb.

☐**1-4.** In the space provided in your Record Book, list the colors in the order you see them in the spectrum produced by the bulb. If you find any differences between this spectrum and the one produced by sunlight, list them. Look especially for differences in how strongly certain colors show up and for any bright or dark lines.

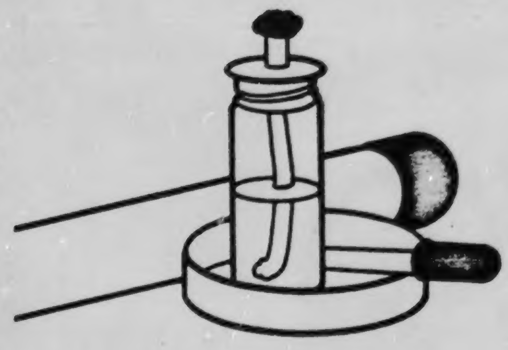
☐**1-5.** Next, use your spectroscope to examine the light from a fluorescent tube. Once again, list the colors in the spectrum in the order you see them. Also, describe any differences between the spectrum from the fluorescent tube and the spectrum formed by sunlight.

If you made careful observations, you should have noticed some bright lines in the fluorescent-tube spectrum that you didn't see either in the sun's spectrum or in the spectrum from the light bulb. Also, some of the colors may have shown up more clearly in one spectrum than another. What do these differences mean?

To find out, you'll need to work with a partner. You will be using the spectroscope to look at the light given off from heated substances. Therefore, you will need to work in semi-darkness. If a part of your room cannot be darkened, then rig your own work space as shown in Activity 1-4.



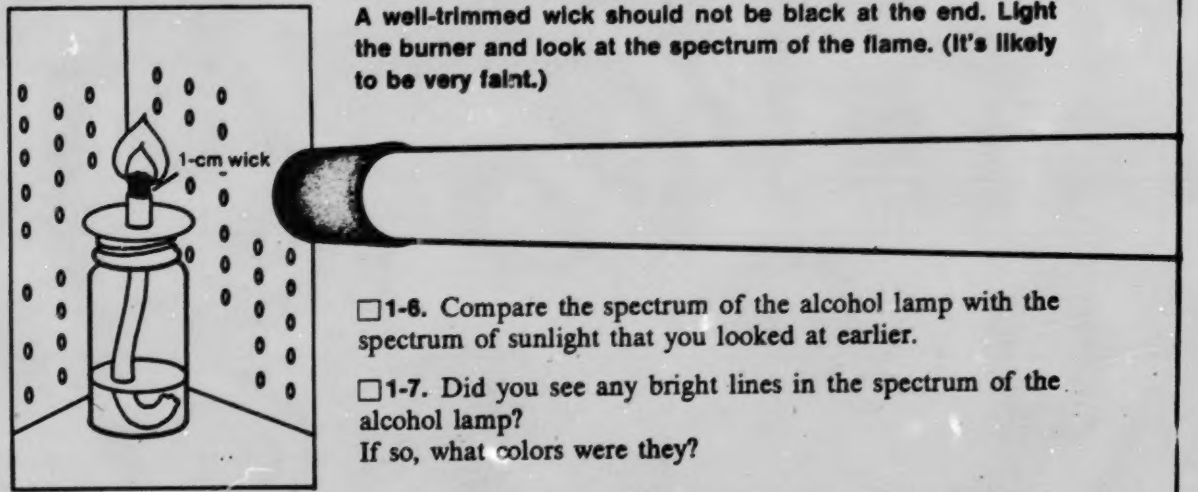
ACTIVITY 1-4. Set up two pegboard backs as shown. Put another piece of pegboard or other nonburnable shield across the top of the pegboards to give more shade.



Now get the following materials from the supply area:

3 pieces of nichrome wire, each 10 cm long
1 alcohol burner
3 petri dishes
1 spectroscope
1 small container of water
1 eyedropper
3 pieces of masking tape, each 3 cm long
Lithium chloride crystals
Strontium chloride crystals
Sodium chloride crystals

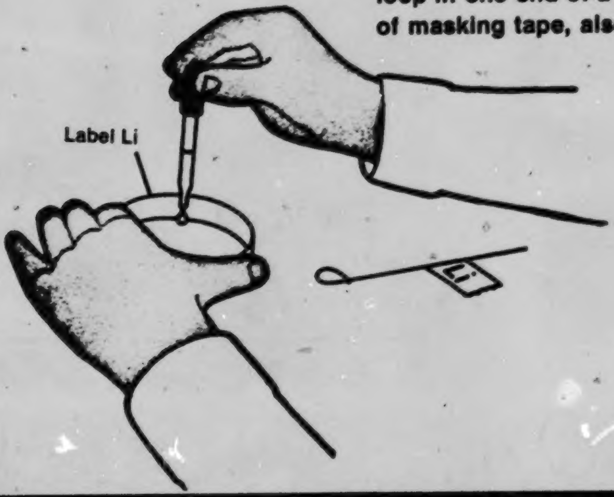
ACTIVITY 1-5. Pull 1 cm of the wick out of the alcohol burner. A well-trimmed wick should not be black at the end. Light the burner and look at the spectrum of the flame. (It's likely to be very faint.)

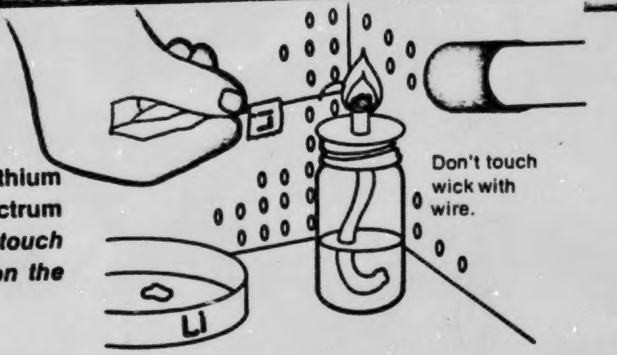


☐**1-6.** Compare the spectrum of the alcohol lamp with the spectrum of sunlight that you looked at earlier.

☐**1-7.** Did you see any bright lines in the spectrum of the alcohol lamp?
If so, what colors were they?

ACTIVITY 1-6. Mix the crystals of lithium chloride with 2 drops of water in a petri dish labeled "Li" (lithium). Make a small loop in one end of a nichrome wire and attach a small piece of masking tape, also labeled "Li."





ACTIVITY 1-7. Dip the loop of nichrome wire into the lithium chloride solution. While your partner looks at the spectrum of the alcohol flame, put the loop into the flame. *Do not touch the wick with the loop. Try not to get any chemicals on the wick.* Take turns looking at the spectrum.

☐**1-8.** In the space provided in your Record Book, show the position of any bright lines you saw in the spectrum. Compare your sketch with the lithium spectrum shown in Figure 1-2.

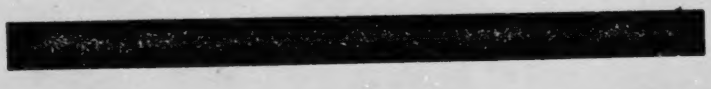
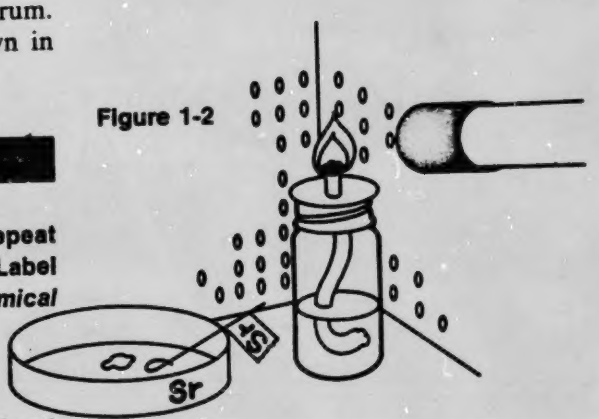


Figure 1-2



ACTIVITY 1-8. Using a clean dish and a clean wire, repeat Activities 1-6 and 1-7, using strontium chloride crystals. Label the dish and wire "Sr." *Again, do not get any of the chemical on the wick.*

☐**1-9.** In the space provided in your Record Book, sketch any bright lines you saw in the strontium spectrum. Then compare your sketch with the Sr Spectrum in Figure 1-3.

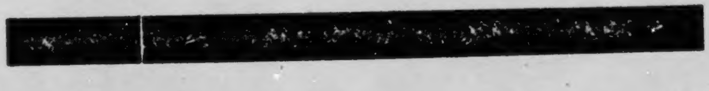
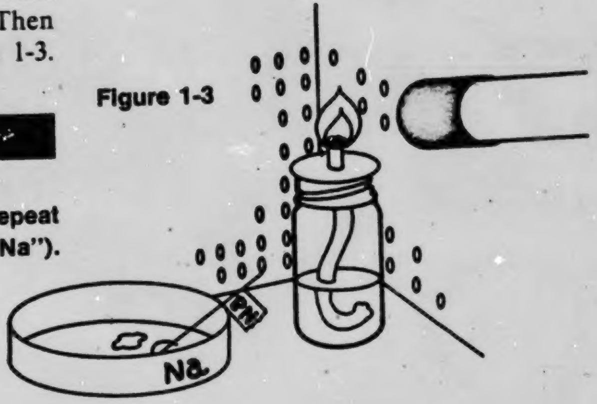


Figure 1-3



ACTIVITY 1-9. With a third clean dish and clean wire, repeat Activities 1-6 and 1-7, using sodium chloride (label "Na").

☐**1-10.** Sketch any bright lines you saw in the sodium spectrum. Then compare your sketch with the Na spectrum shown in Figure 1-4.

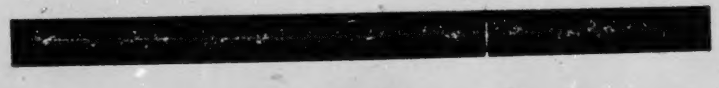


Figure 1-4

The spectrum of an element heated in a fairly colorless flame is just a few bright lines. This type of spectrum is called a bright-line spectrum. Each element produces a definite set of bright lines. Scientists have found that they can identify an element by its bright lines as surely as they can identify you by your fingerprints. The bright lines you saw earlier in the fluorescent-tube spectrum were due to the gases in the tube (mostly mercury vapor).

From time to time in this unit, you will be asked to do "problem breaks." These are problems for you to solve, without much help from your book or from your teacher. The problems will usually help you understand what you are studying in the chapter. But that's not their major purpose. They are designed to give you practice in problem solving, and in setting up your own experiments. You should try every problem break—even the tough ones. And in most cases you should have your teacher approve your plan before trying it. The first problem break in this unit is coming up next.

PROBLEM BREAK 1-1

Now here's some detective work for you. Your teacher has prepared a solution of one, two, or three of the substances you just tested (sodium chloride, lithium chloride, and strontium chloride). Your job is to find out which substance or substances was used.

☐**1-11.** In the space provided in your Record Book, show the position of any bright lines you identify.

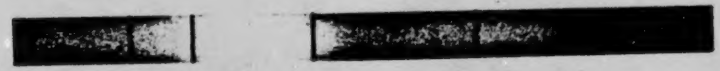
☐**1-12.** Compare the sketch you made with the sketches you made in answer to questions 1-8, 1-9, and 1-10. What substance or substances do you predict are in the unknown solution?

Check your prediction with your teacher.

Astronomers use spectroscopes to identify the elements in the stars. In fact, the spectral lines of the element helium were first observed in sunlight. When the substance that produced these lines was finally found on the earth, it was named helium (from the Greek word *helios*, meaning "sun").

The spectrum of helium is shown in Figure 1-5. You should notice a peculiar difference in this spectrum when it is compared to others you have observed.

Figure 1-5



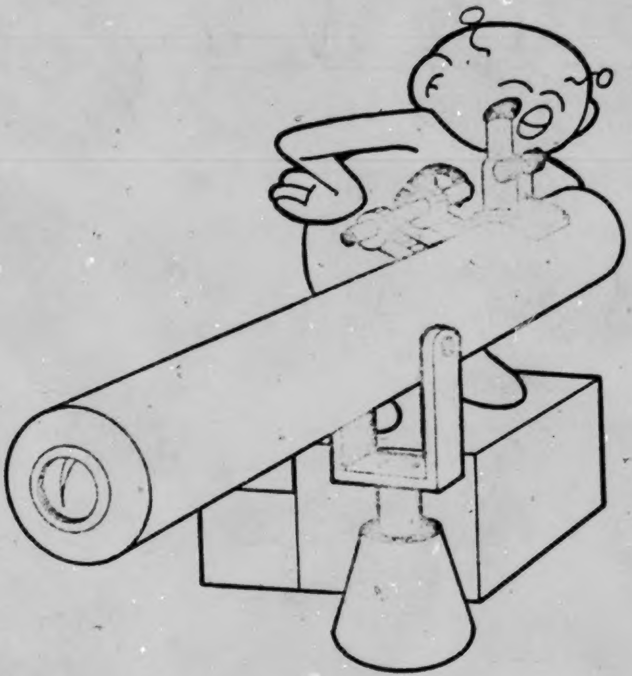
EXCURSION

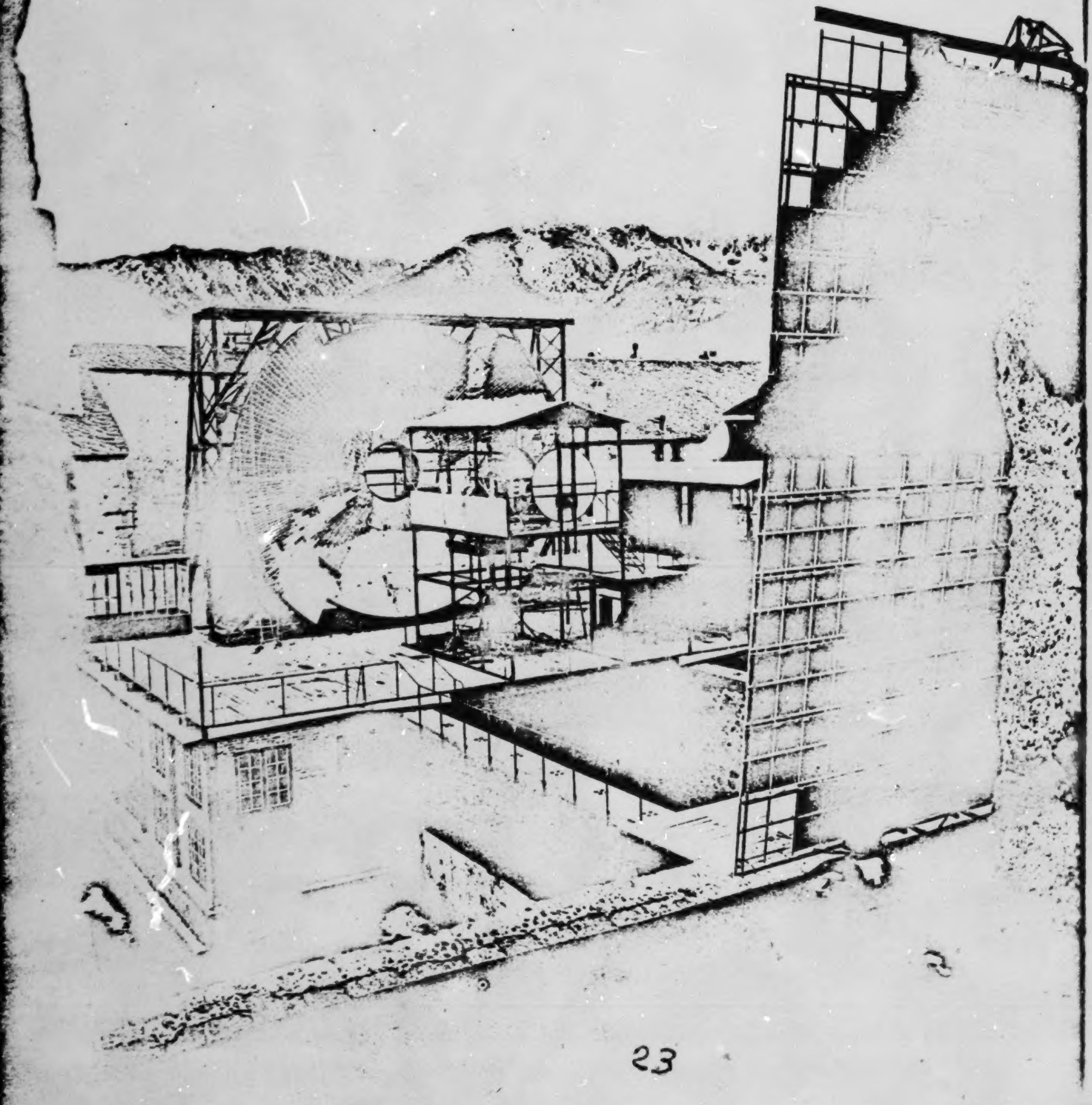
Perhaps you would like to learn more about the kind of spectrum shown in Figure 1-5. You can find out how they were discovered and how to see one yourself by doing **Excursion 1-1.**

Bright lines and dark lines in spectra can tell astronomers a great deal about the composition of stars and planets. Most of what we know about the sun and its atmosphere is a direct result of information from spectra.

In Chapter 2 you will see how to take the first step in measuring the amount of energy released by the sun. Fortunately you won't have to go there to do it.

Before going on, do Self-Evaluation 1 in your Record Book.



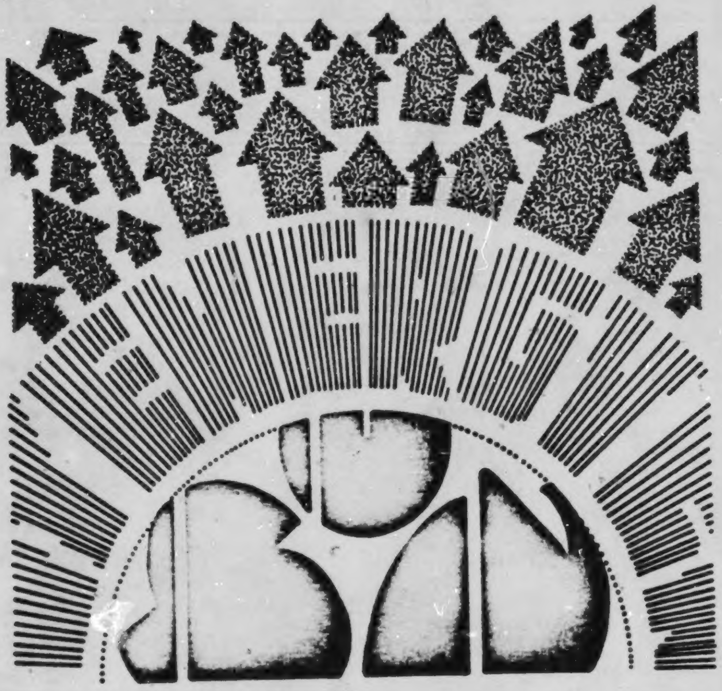


Watts New?

Chapter 2

Everybody knows that the sun gives off lots of energy. In fact, you may have heard that all energy on the earth comes, in one way or another, from the sun. But what does it mean to say "lots of energy"? How much is "lots"? That is the problem for this chapter—to get an idea of how much energy the sun gives off.

To be sure you are ready to begin the next activity, you need to know some things about energy. The following checkup will help you find out whether you are ready to go ahead.



CHECKUP

In your Record Book, place a check mark in front of each correct answer. There may be more than one correct answer per question.

1. Work is
a. force
b. distance.
c. force × distance.
d. speed × time.

2. A measure of energy is
a. force.
b. force × distance.
c. speed × time.
d. work.

3. Energy can
a. exist only in the form of heat.
b. exist in more than one form.
c. be transferred from one system to another.
d. cause changes in matter.

4. Energy is always
a. conserved.
b. destroyed.
c. needed to overcome forces.
d. a measure of the time needed to do work.

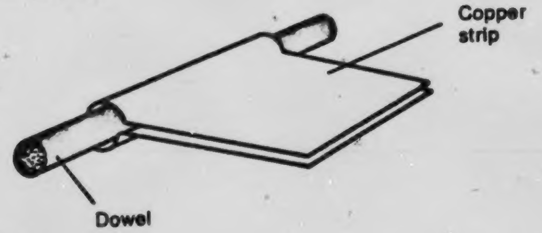
EXCURSION

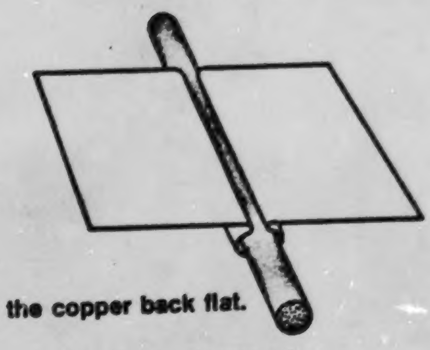
Check your answers on page 77 of **Excursion 2-1.**

To begin making a sun-energy indicator, you will need these things:

1 strip of copper, 6 cm × 3 cm
1 Celsius thermometer
1 piece of dowel, the same diameter as the thermometer bulb
1 candle
Matches
Paper clip

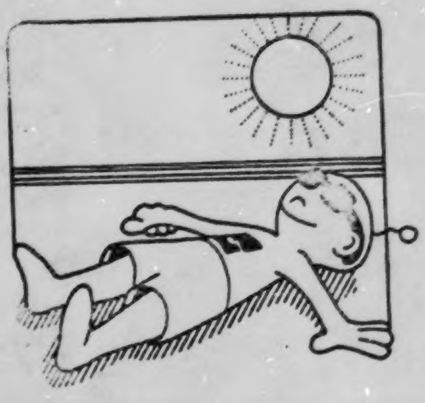
ACTIVITY 2-1. Pinch the strip of copper tightly around the dowel as shown.





ACTIVITY 2-2. Bend the ends of the copper back flat.

As you know, that part of the sun's energy that reaches the earth is in the form of light. A large portion of this light energy changes to heat energy when it reaches the earth's atmosphere and surface. This heating effect is what causes objects put in sunlight to get hotter. How much the temperature of an object increases depends on

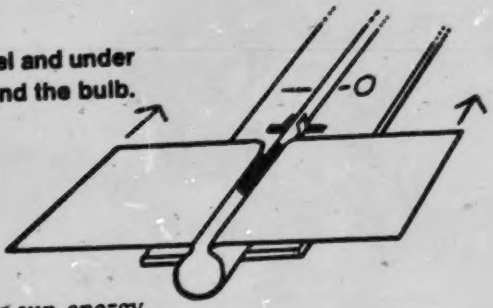


1. how big the object is,
2. how well it absorbs heat,
3. how quickly it conducts heat, and
4. how long it is heated.

Each of these factors affects how much change in temperature will be observed when the object is placed in the sun.

All of this means that you can get an idea of how much heat is absorbed by an object by measuring its temperature before and after placing it in the light. All you need is an object to be heated, and a thermometer.

ACTIVITY 2-3. Slide the copper strip from the dowel and under the bulb of the thermometer. Gently pinch it around the bulb. *Use care so as not to break the thermometer.*



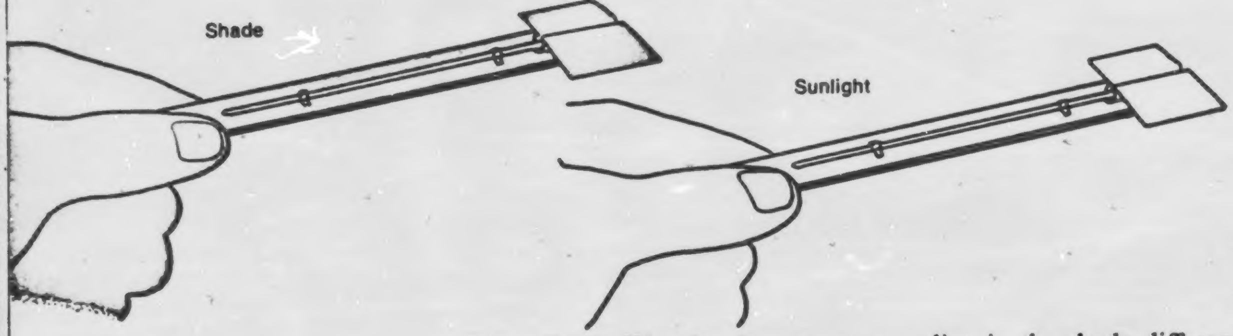
By now, you've probably figured out how your sun-energy indicator will work.

☐**2-1.** What do you predict will happen to the copper strip if it is placed in sunlight?

☐**2-2.** What is the purpose of the thermometer?

Now let's test the energy indicator you've built.

ACTIVITY 2-4. Hold the instrument in the shade for a couple of minutes. Then move it into the sun for a few more minutes. Do not rest it on any surface.



☐**2-3.** Was the thermometer reading in the shade different from that in the sun? (If so, how much?)

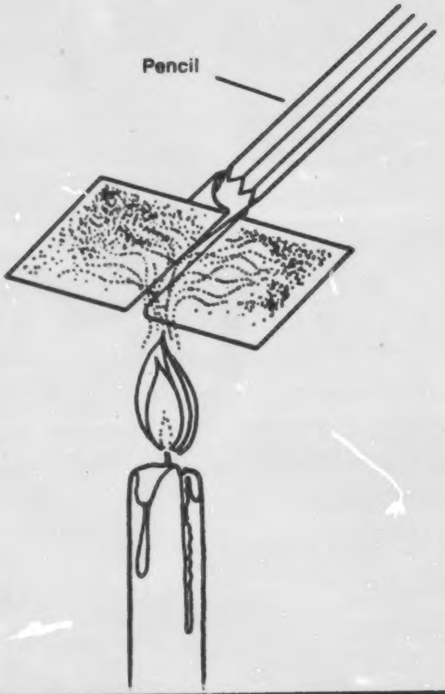
If the thermometer didn't show a temperature change, something is wrong. The copper strip should have absorbed enough energy to affect the thermometer. If it didn't, check Activities 2-1, 2-2, and 2-3 to be sure that you put the instrument together correctly.

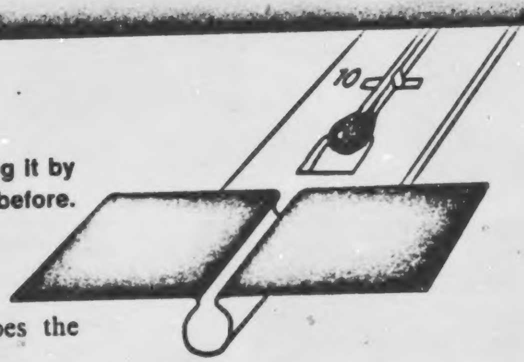
You should make one improvement in your sun-energy indicator before you use it. You probably noticed that the temperature change was slow in occurring. The amount of temperature change was probably rather small, too. It would help matters if the copper absorbed energy more quickly than it does.

Copper is a shiny metal. This means that it reflects some light. If you could cut down its shininess, the copper would convert more light energy to heat.

☐**2-4.** What could you do to the copper to make it absorb more of the sun's energy?

ACTIVITY 2-5. Slide the copper strip off the thermometer. Insert a pencil or dowel in the bend of the strip. Hold the copper over a lighted candle. Try to cover the flat surface evenly with soot from the candle. *Warning Do not hold the thermometer over the candle, as it will get hot and break.* If you get wax on the strip, you must clean it and start again.





ACTIVITY 2-6. Let the copper strip cool. Then, holding it by the unblackened loop, attach it to the thermometer as before.

Test your instrument in a sunny spot.

☐**2-5.** At room temperature, what temperature does the sun-energy indicator show?

☐**2-6.** What temperature does the instrument show after being in direct sunlight for a few minutes?

☐**2-7.** By how many degrees did the temperature change?

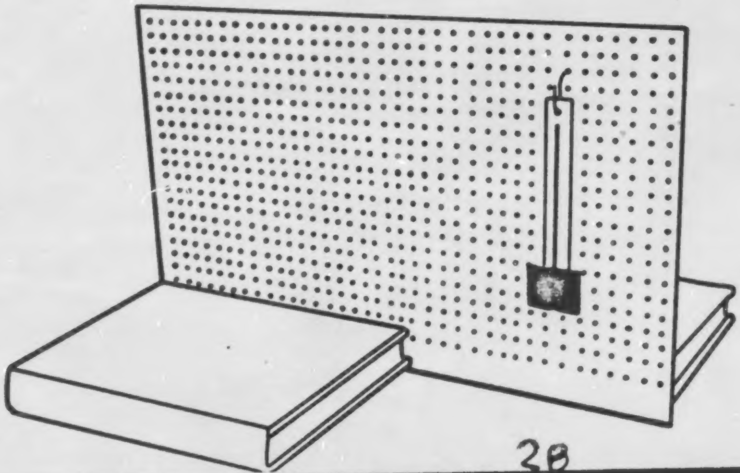
Remove the sun-energy indicator from the sunlight and let it return to room temperature.

☐**2-8.** Why do you think copper was a good choice of metal?

With this instrument you should be able to get an idea of how much energy is received by the copper strip from the sun in a given amount of time.

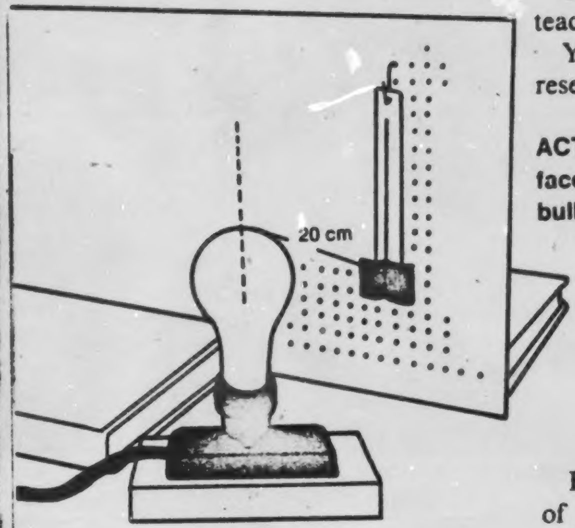
By now you may be seeing some problems in using the sun-energy indicator. Suppose, for example, you got a reading in the sun 20° higher than in the shade. This would tell you that the copper strip had absorbed energy. But it would certainly not tell you how much total energy the sun gives off. To learn that, you would need to know several other things. The next activities will help you find out what they are. Pick up a pegboard and a paper clip.

ACTIVITY 2-7. Hang the sun-energy indicator in an upright position as shown. You can make a hanger from a paper clip.



Carry the stand with the attached instrument to where your teacher has set up a series of light bulbs.

You will use these bulbs as a light source. They will represent the sun.



ACTIVITY 2-8. Place the pegboard so that the blackened surface of the copper strip is 20 cm from the center of one 150-watt bulb in the parallel circuit.

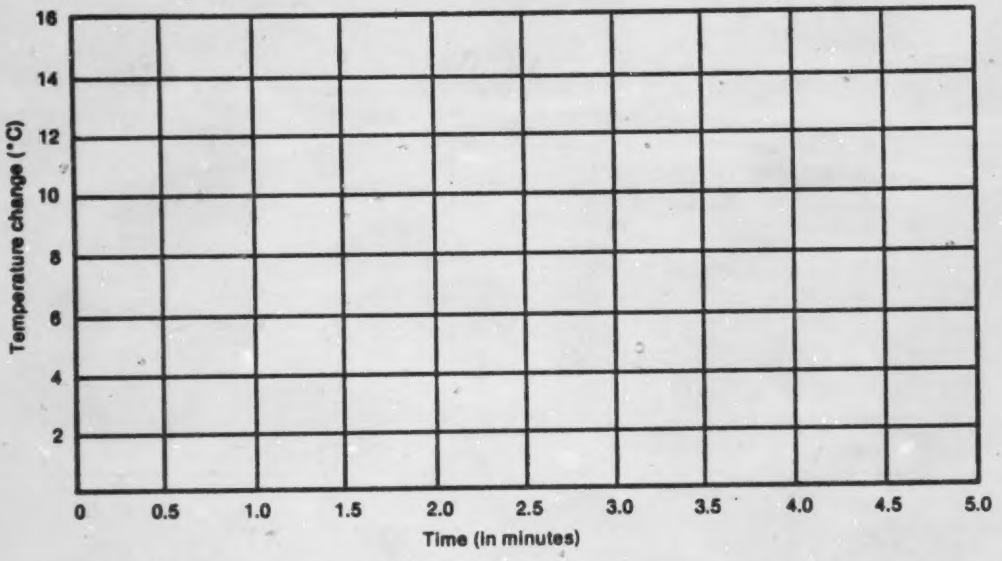
Record the temperature of the thermometer in Table 2-1 of your Record Book. Then turn on the lamp. Every 30 seconds, record the thermometer reading. Complete the table by calculating what the total temperature change has been up to each of the times indicated (new temperature minus the temperature at 0.0 time).

Table 2-1

Time (minutes)	Temperature (°C)	Total Temperature Change (°C)
0.0		
0.5		
1.0		
1.5		
2.0		
2.5		
3.0		
3.5		
4.0		
4.5		
5.0		

Graph your results on the grid of Figure 2-1 in your Record Book. Use the data from the Total Temperature Change column and from the Time column.

Figure 2-1



☐**2-9.** According to your graph, how many minutes passed before the temperature stopped rising?

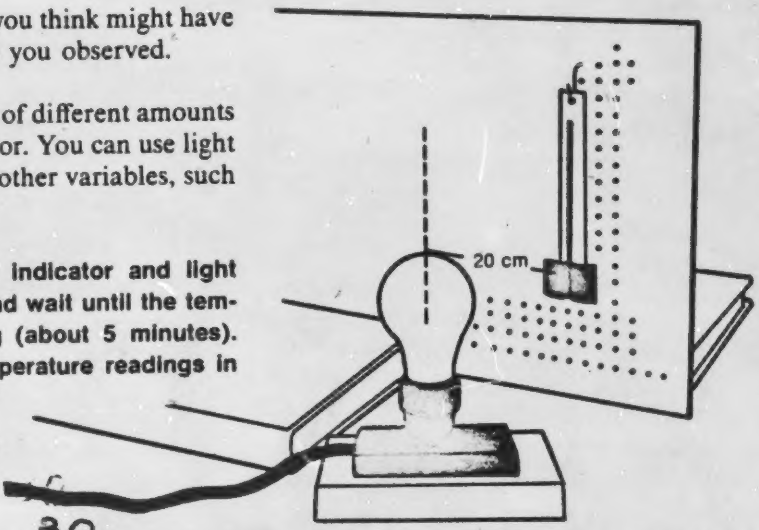
☐**2-10.** Why do you think the temperature stopped increasing?

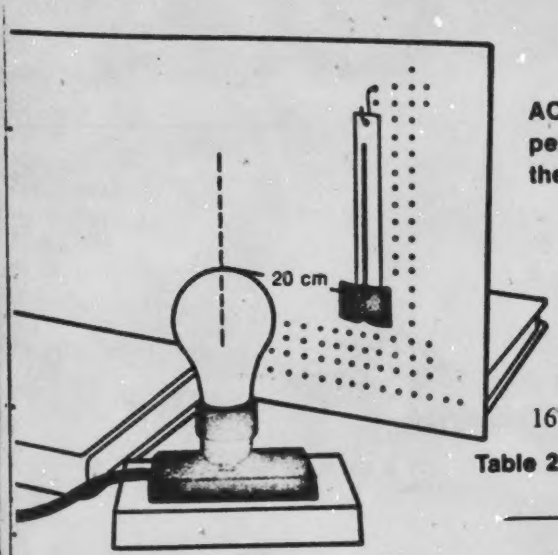
Place the sun-energy indicator away from the light so that it can cool to room temperature.

☐**2-11.** List at least three variables that you think might have affected how much temperature change you observed.

You should now investigate the effects of different amounts of light energy on the sun-energy indicator. You can use light bulbs of different sizes. Be sure to keep other variables, such as time and distance, constant.

ACTIVITY 2-9. Set up the sun-energy indicator and light source as shown. *Use a 60-watt bulb* and wait until the temperature reaches its maximum reading (about 5 minutes). Record the original and maximum temperature readings in Table 2-2 of your Record Book.





ACTIVITY 2-10. Allow the thermometer to return to room temperature. Repeat Activity 2-9, using a 100-watt bulb. Record the data in Table 2-2.

Use data from the 0.0 and 5.0 lines of Table 2-1 on page 16 to fill in the spaces in Table 2-2 for the 150-watt bulb.

Table 2-2

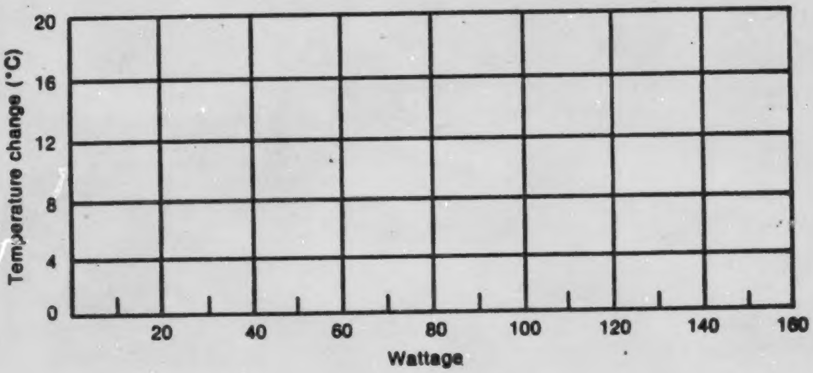
Bulb	Original Temperature	Maximum Temperature	Temperature Change
60w			
100w			
150w			

The watt number on a bulb tells you how much energy it produces. The greater the wattage, the greater the energy produced.

☐**2-12.** Which of the following bulbs produces the most light energy: 150W, 60W, or 100W?

Complete the last column in Table 2-2, and graph your results in Figure 2-2 of your Record Book.

Figure 2-2



☐**2-13.** What happened to the temperature change as the wattage (amount of energy) of the bulb increased?

☐**2-14.** Look at your graph in Figure 2-2. Predict the amount of temperature change you would have recorded if you had used a 50-watt bulb.

☐**2-15.** Suppose the 50-watt bulb had been placed 40 cm from the strip instead of 20 cm. Predict how this would have affected the amount of temperature change.

PROBLEM BREAK 2-1

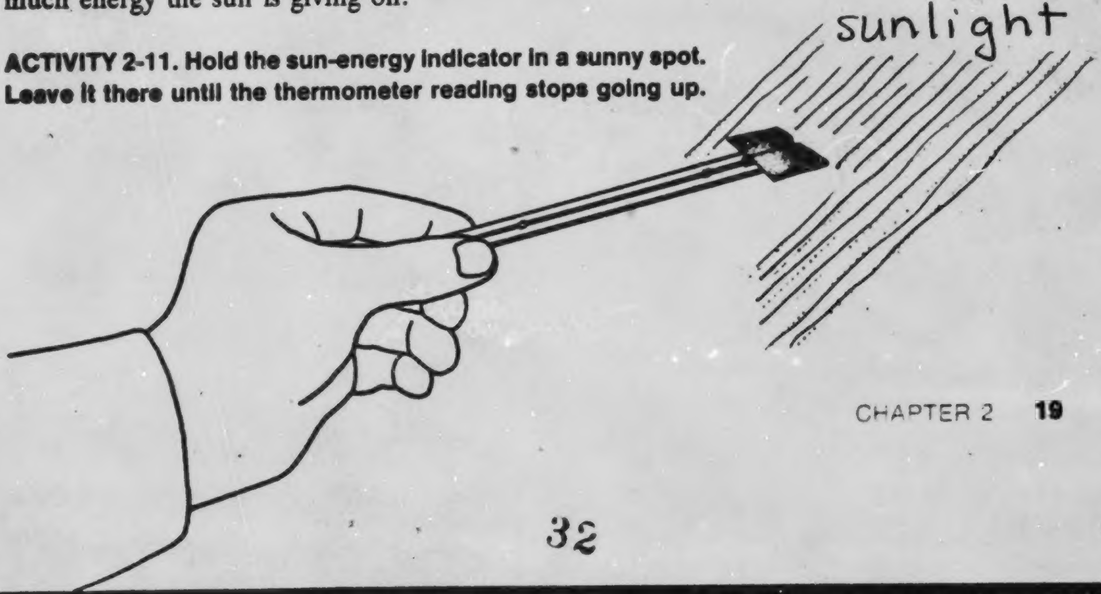
Get a 50-watt bulb and test your predictions for questions 2-14 and 2-15. How much does the reading of the sun-energy measurer change when you double the distance between it and a light source? Suppose you tripled the initial 20-cm distance. Would the temperature reading decrease to one third of what it was at 20 cm?

In your Record Book, describe an experiment you could do to study the relationship between distance and temperature change. Have your teacher approve your design before doing the experiment. Record your data in your Record Book in the form of a graph with at least *eight data points.*

☐**2-16.** In your experiment, why should you keep the wattage of the light source constant at 50 watts?

Now let's return to the problem that started this chapter. Let's try to use your sun-energy indicator to find out how much energy the sun is giving off.

ACTIVITY 2-11. Hold the sun-energy indicator in a sunny spot. Leave it there until the thermometer reading stops going up.



☐**2-17.** How much temperature change did the sun-energy indicator show?

Now look at your graph from Problem Break 2-1.

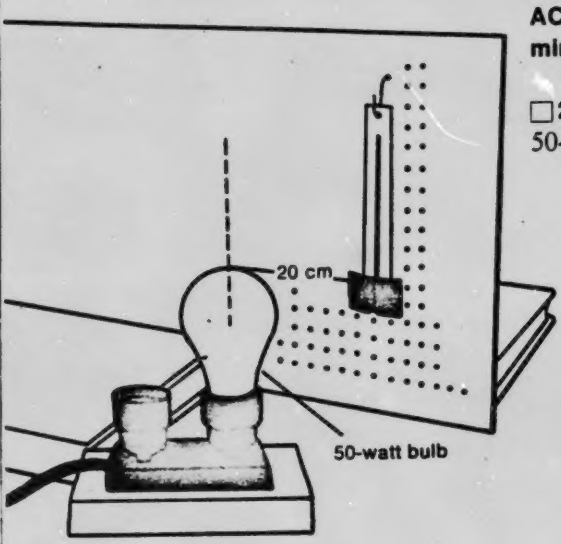
☐**2-18.** At what distance from a 50-watt bulb must the indicator be placed to show the same temperature as it did in direct sunlight?

Test your answer to question 2-18 by placing the sun-energy indicator at the distance you gave.

You know that the sun gives off a lot more energy than a 50-watt bulb. But because it's so far from the earth, the energy that reaches the copper strip from the sun is no greater than that from the much closer bulb. The distance an object is from the light source has a great effect on the amount of energy received by the object. Therefore, when calculating the energy produced by the sun, its distance must be an important factor.

An accurate measure of the sun's energy must include its distance from the earth. In a later investigation you will measure that distance. For now, you can only get an idea of how great is the sun's total energy output. To do this, you will need to take your sun-energy measurer over to the area where the bulbs in parallel circuits are located.

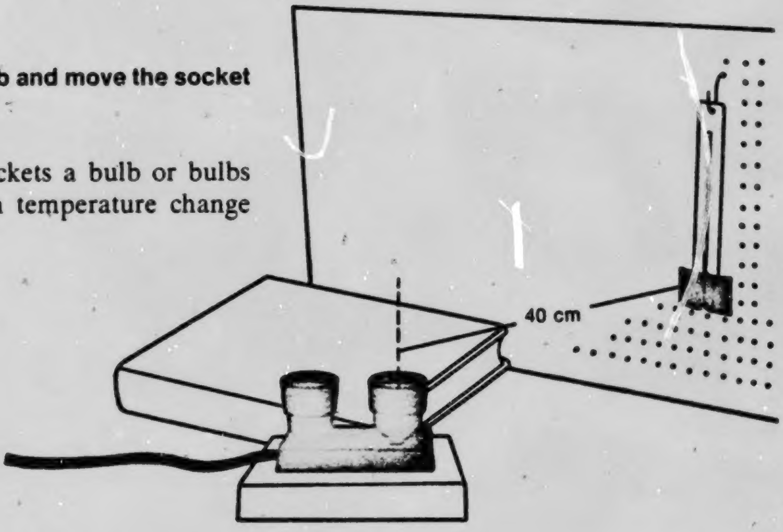
ACTIVITY 2-12. Set up your apparatus as shown. After 5 minutes, note the temperature.



☐**2-19.** Record the highest temperature reading from the 50-watt bulb at 20 cm.

ACTIVITY 2-13. Remove the 50-watt bulb and move the socket 40 cm from the sun-energy measurer.

Your problem is to place in the sockets a bulb or bulbs that will produce the same maximum temperature change that you found in Activity 2-12.



☐**2-20.** What wattage (energy) bulb or bulbs do you predict will produce this reading?

Add bulbs to the sockets until you find one, or a combination, that produces roughly the reading you are looking for. Be sure that the bulbs are 40 cm from the sun-energy measurer.

☐**2-21.** How many 50-watt bulbs would you need at 40 cm to give the same temperature reading that one 50-watt bulb gave at 20 cm?

☐**2-22.** Suppose you moved the sockets to 80 cm. How many 50-watt bulbs would you have to use to produce the same reading as one 50-watt bulb at 20 cm?

Now think how many 50-watt bulbs you would need if you moved the socket out a mile from the energy indicator. You'd have to have a tremendously large source of energy to give the same reading.

The sun is many, many miles from the earth. With what you know now, you can be sure that the sun is giving off a tremendous amount of energy. To give a good estimate of how much, you will need to know how many miles away the sun is. That is the subject of the next chapter—the way to measure the distance from the earth to the sun.

Before going on, do Self-Evaluation 2 in your Record Book.

35

Far-Out Sun

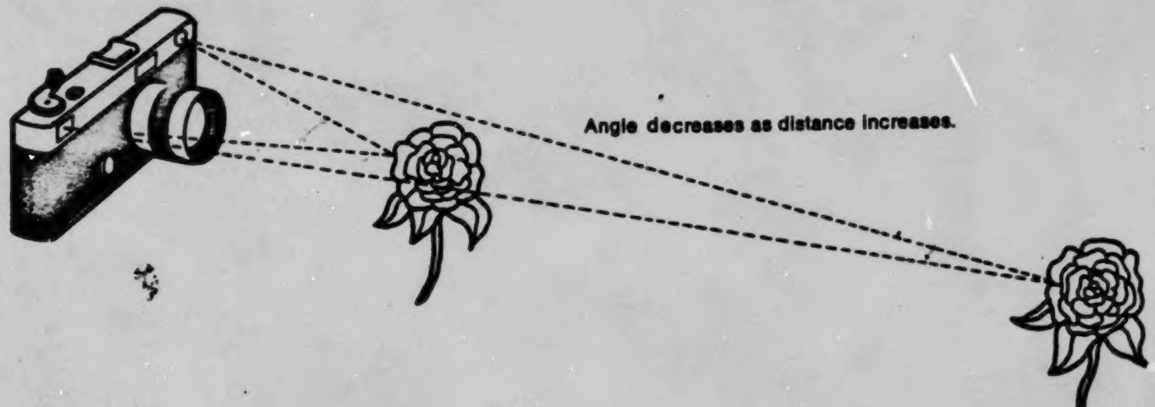
Chapter 3

Measuring the distance to the sun may seem like an impossible job to you. More than likely, you've always used a ruler or meterstick to measure distances, but such a device won't work for measuring the distance to the sun.

Actually, the problem won't be as difficult as you may think. In many ways, you're in the same boat as a hunter—or a photographer—who wants to know the distance to an animal. If he tries to use a ruler or tape measure, he won't get many shots.

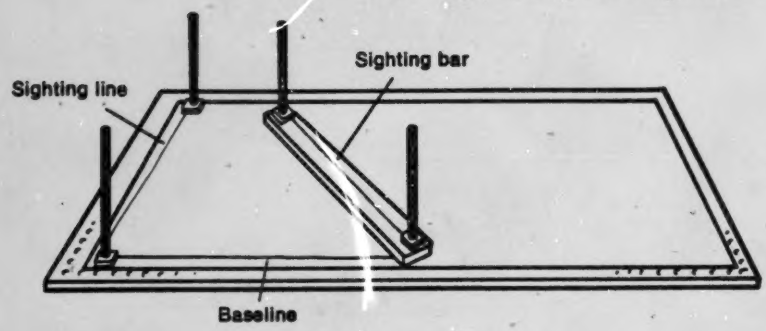
Both camera and rifle manufacturers have solved the problem in the same way. Many guns and cameras include a device called a range finder. In using a range finder, a person looks at an object from two different angles. The device evaluates the distance to the object from the size of the angles formed. (See Figure 3-1.)

Figure 3-1



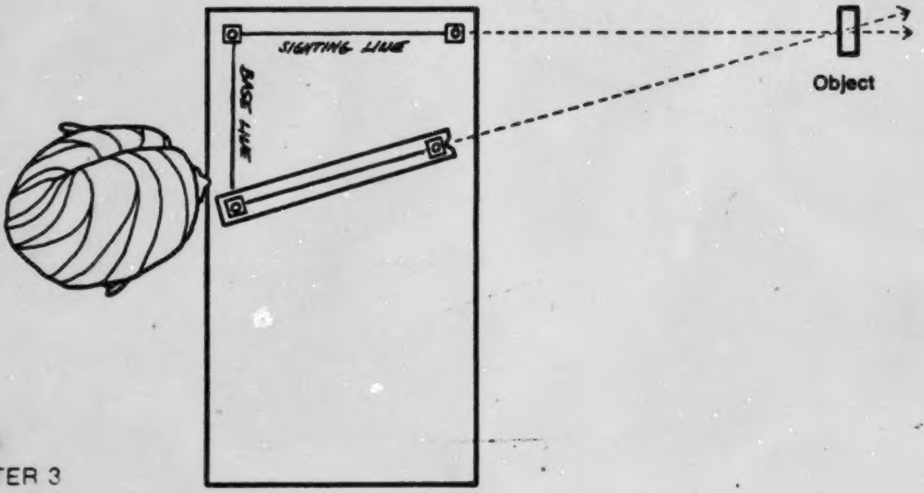
You can use a simple homemade range finder that will help you measure the distance to the sun. Get one from the supply area.

ACTIVITY 3-1. Look the range finder over carefully. Note particularly the labeled parts. Draw and label the sighting line and base line on your range finder if this has not been done.

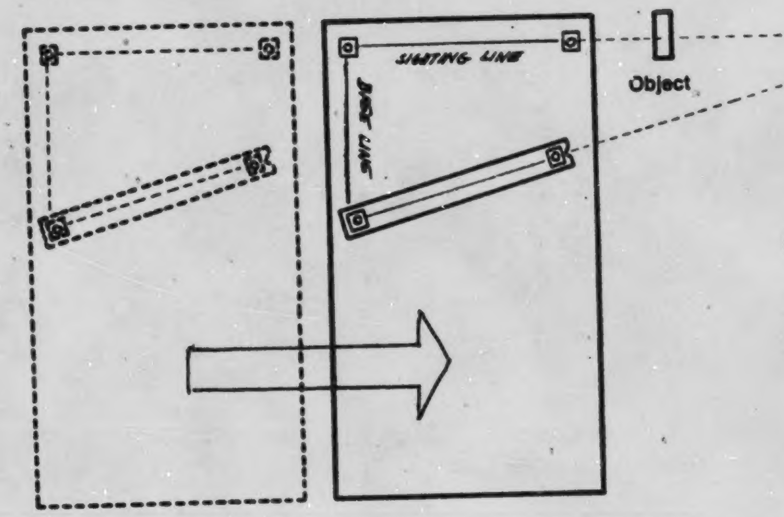


Before you try to measure the distance to the sun with the range finder, you should learn how it works. Pick out an object to look at on the other side of your classroom.

ACTIVITY 3-2. Place the range finder on a flat surface and line up the sighting line with the object. Without moving the pegboard, adjust the sighting bar until it lines up with the object. When you are finished, both the sighting line and sighting bar should be lined up with the object.



ACTIVITY 3-3. Move the range finder along the sighting line until it is several feet closer to the object. ***Don't change the position of the sighting bar.***

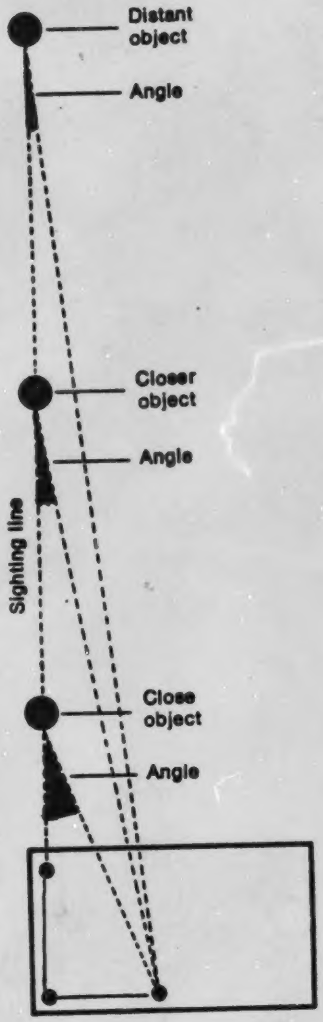

SIGHTING LINE
BASE LINE
Object

☐**3-1.** Does the sighting bar still line up with the object after the range finder is moved? If not, what would you have to do to line it up?

☐**3-2.** Suppose you were to move the range finder even closer to the object along the sighting line. Predict what you would have to do to align the sighting bar.

Perhaps you are beginning to understand the principle upon which the range finder works. As the device is moved closer to an object, the angle between the sighting bar and the sighting line changes.

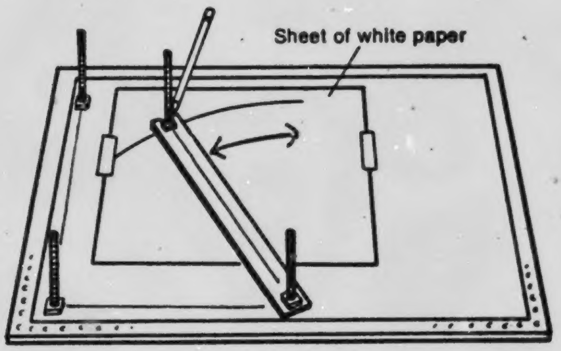
☐**3-3.** Suppose the distance from the range finder to an object increases. In what way do you predict the angle between the sighting line and sighting bar will change?


Distant object
Angle
Closer object
Angle
Sighting line
Close object
Angle

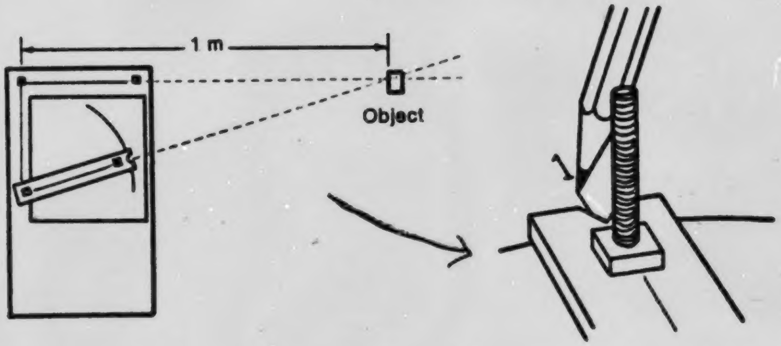
Test your prediction in question 3-3 by doing the next activity.

Your teacher has chosen an object in your room and placed marks on the floor at distances from it of 1, 2, 3, 4, 5, 10, and 15 meters.

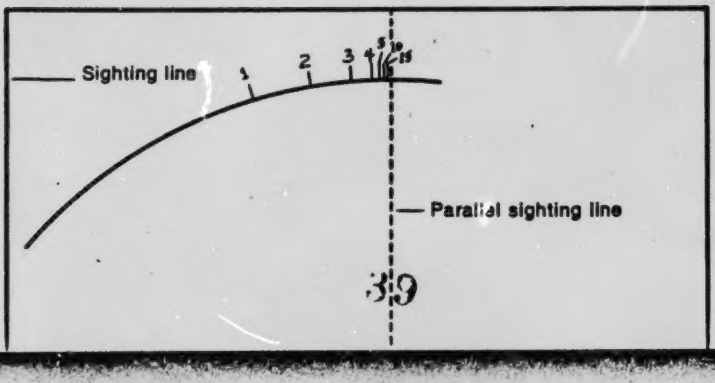
ACTIVITY 3-4. With small pieces of tape, attach a sheet of white paper to the range finder as shown. Place the tip of a pencil into the groove at the end of the sighting bar. Turn the bar to draw part of a circle.


Sheet of white paper

ACTIVITY 3-5. Place the range finder so that the sighting line rear bolt is at the 1-m mark on the floor. Line up the sighting line, and then the sighting bar, with the object. When you are sure the position of the bar is correct, make a mark on the circle as shown, and label the mark "1."



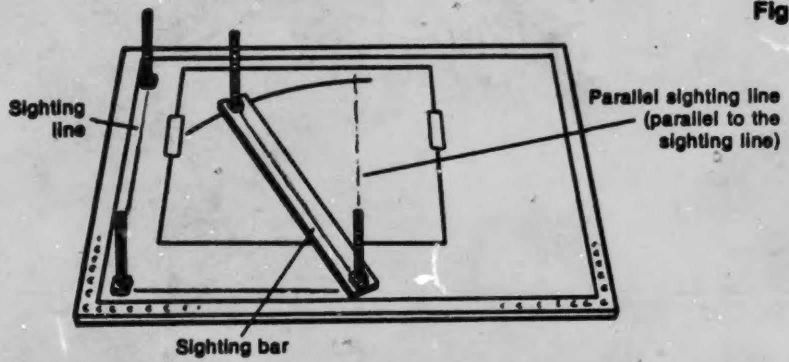
ACTIVITY 3-6. Repeat Activity 3-5 for distances of 2m, 3m, 4m, 5m, 10m, and 15m. When your scale is complete, it should appear similar to that shown. Label each mark.


Sighting line
1
2
3
4
5
10
15
Parallel sighting line

Practice using your range finder to measure the distance to objects not more than 15m away. Check your measurements with a meterstick. If they are inaccurate by more than ½m, repeat Activities 3-4, 3-5, and 3-6.

☐**3-4.** Was your prediction in question 3-3 correct? As the distance to an object becomes greater, what happens to the angle formed by the sighting bar and the parallel sighting line shown in Figure 3-2?

Figure 3-2



☐**3-5.** Suppose you lined up the sighting line and the sighting bar of the range finder in Figure 3-2 on an object a long way off (like a distant tree). Would you expect the angle between the sighting bar and the parallel sighting line to be large or small?

Check your prediction by using your own range finder. (Draw a parallel sighting line on your range finder if it will help you.)

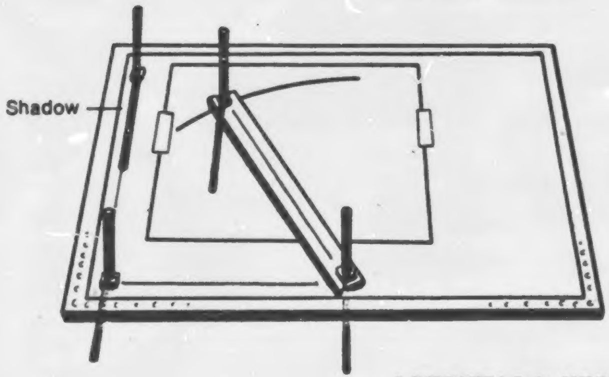
Select two very distant objects, one of which is farther away than the other—a distant tree and building perhaps. Use the range finder to decide which of the objects is farther away.

☐**3-6.** Describe any problems you had in deciding which object was farther away.

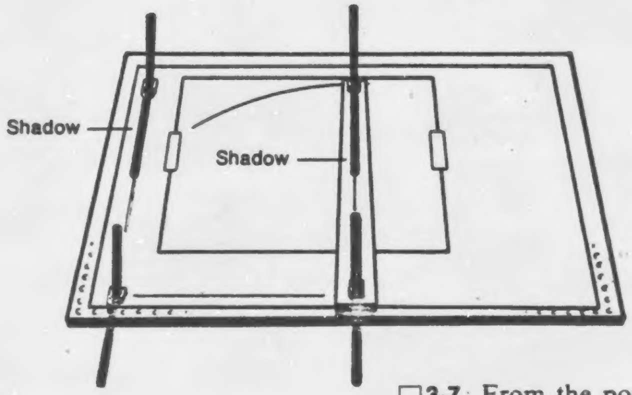
Well, by now you should have a good understanding of how to use the range finder. It seems to work fine on short distances but not so well for distances beyond about 15 m. This may limit its usefulness for measuring great distances like the distance to the sun. See if it will.

Safety Note: Because of the danger of looking at the sun directly, you must change slightly your method of sighting. Instead of lining up bolts, you will try to line up the shadows the bolts cast.

ACTIVITY 3-7. Set the range finder in a patch of sunlight so that the shadow from the front bolt falls directly along the sighting line.



ACTIVITY 3-8. ***Without moving the pegboard,*** **move the sighting bar until the shadow from its front bolt falls directly along the bar.**



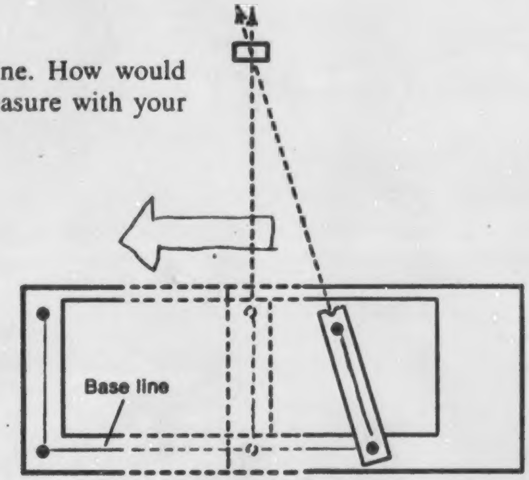
☐**3-7.** From the position of the sighting bar on your scale, what can you say about the distance to the sun?

Clearly, you have a problem. There seems to be a limit to the distance you can measure accurately with your range finder.

One variable that limits the distance that can be measured is the length of the range finder's base line.

41

☐**3-8.** Suppose you lengthened the base line. How would this affect the greatest distance you can measure with your range finder?



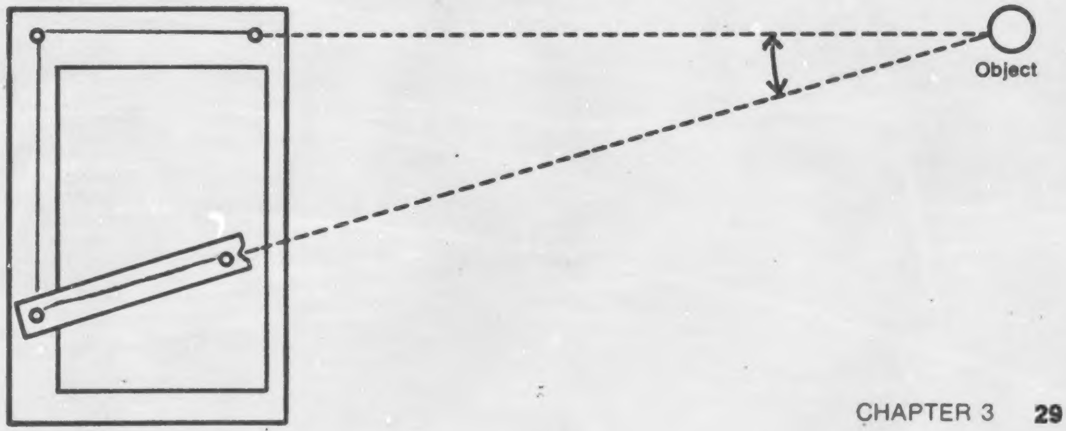
PROBLEM BREAK 3-1

Design an experiment to test the prediction you made in question 3-8. In your Record Book, describe what you would do and what measurements you would make. Check with your teacher and then do the experiment. Record your results and conclusions.

From your experiments, it should be clear that two variables limit the greatest distances that can be measured by your range finder. The first is the length of the base line. The second is the size of the smallest measurable angle between the sighting bar and the parallel sighting line (the sighting angle).

☐**3-9.** In Figure 3-3, how would increasing the base line affect the size of the angle between the two sighting lines?

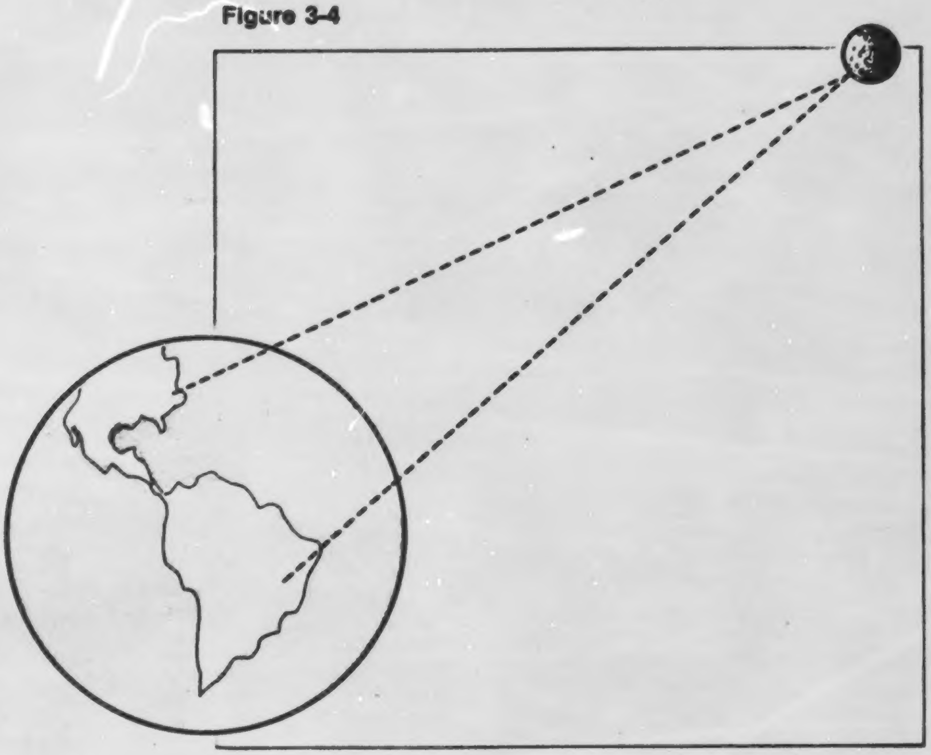
Figure 3-3



Astronomers could make sightings from two observatories that are hundreds or even thousands of miles apart. Figure 3-4 shows how this can be done.

☐**3-10.** If you switched from a simple range finder to the system shown in Figure 3-4, what effect would this change have on the angle?

Figure 3-4



Modern instruments can measure angles of less than 1/1000 of a degree. To increase the base line, sightings of the sun can be made from widely spaced observatories. But even then, the angle turns out to be too small to measure accurately. Unfortunately, the range finder just can't do the job. You must find some other way to measure the distance to the sun. In the next chapter, you will search for a new approach to the problem.

Meanwhile, you might like to know that the distance to the moon has been measured by the range-finder method.

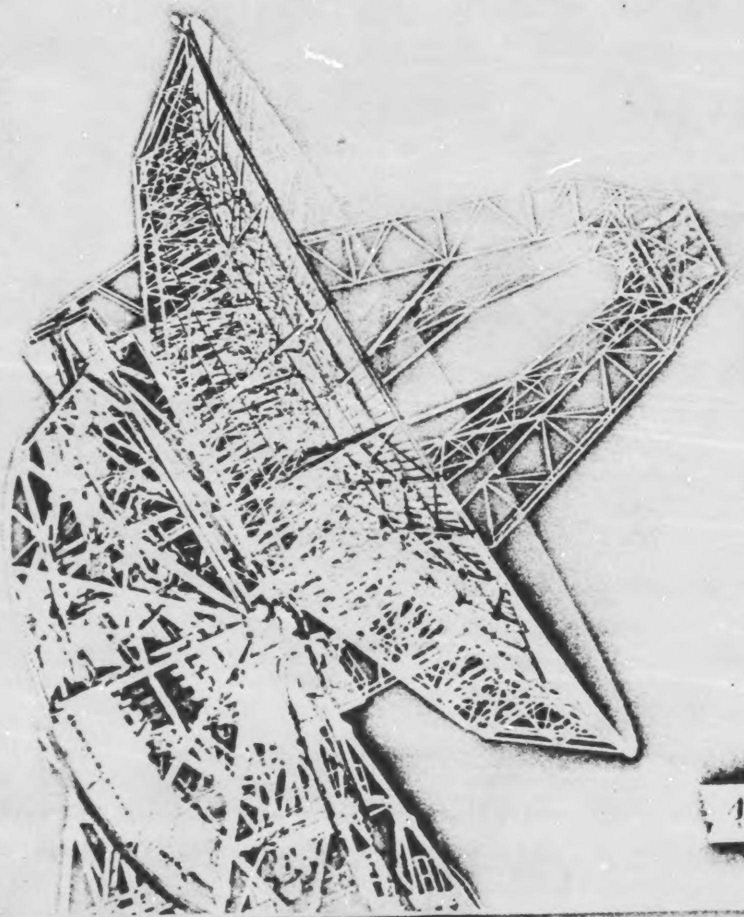
The average distance to the moon is about 240,000 miles. Knowing the distance to the moon makes it simple to find the size (diameter) of the moon.

If you would like to measure the diameter of the moon, **Excursion 3-1** will show you a method that is simple. All you need is a full moon, some time to sit still, and a watch.

EXCURSION

Before going on, do Self-Evaluation 3 in your Record Book.

TIME
= DIAMETER



Measuring the Distance to the Sun—Another Approach

Chapter 4

Some years ago, scientists discovered an interesting way to locate objects at a distance—the use of radar. Using radar, they could get good measurements of the distance to the moon and to some of the planets. They found, for example, that the planet Venus, when closest to the planet Earth, is about 26 million miles away. If you are interested in more information about using radar to measure distances, see **Excursion 4-1.**

The measurement of the distance to Venus has proved to be useful. This distance can be used in determining how far the sun is from Earth. Let's see how.

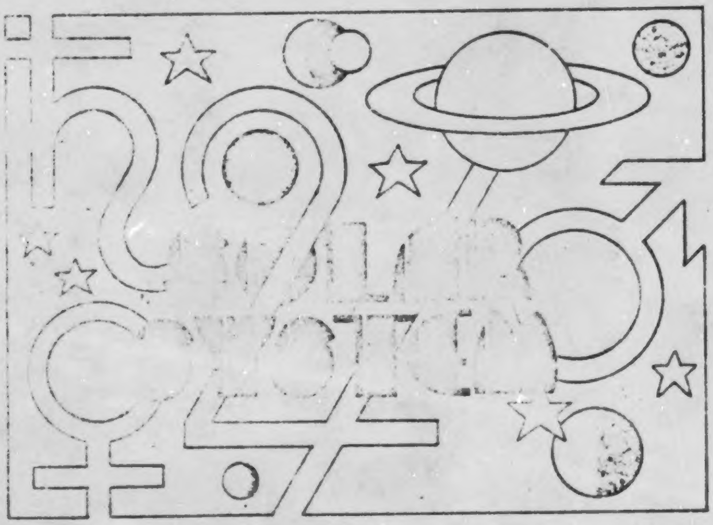


Figure 4-1 shows how the range finder that you used in the last chapter works. Take a close look at the figure; then answer question 4-1.

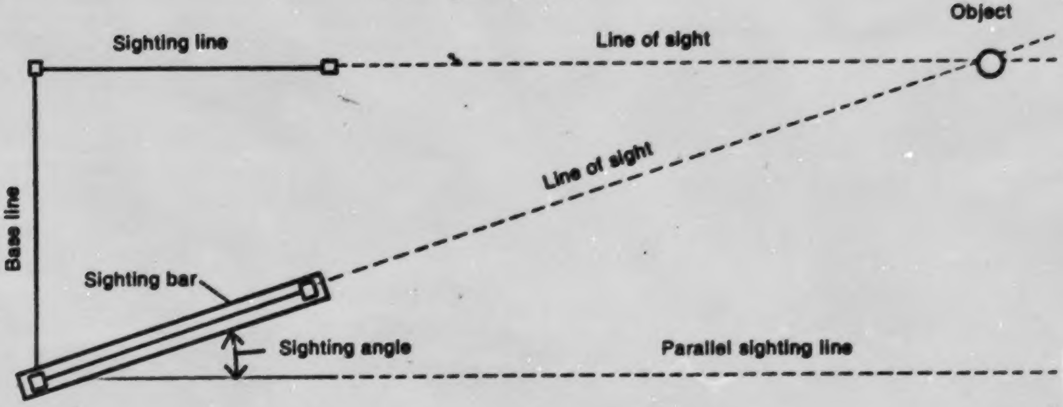

Object
Sighting line
Line of sight
Line of sight
Base line
Sighting bar
Sighting angle
Parallel sighting line

Figure 4-1

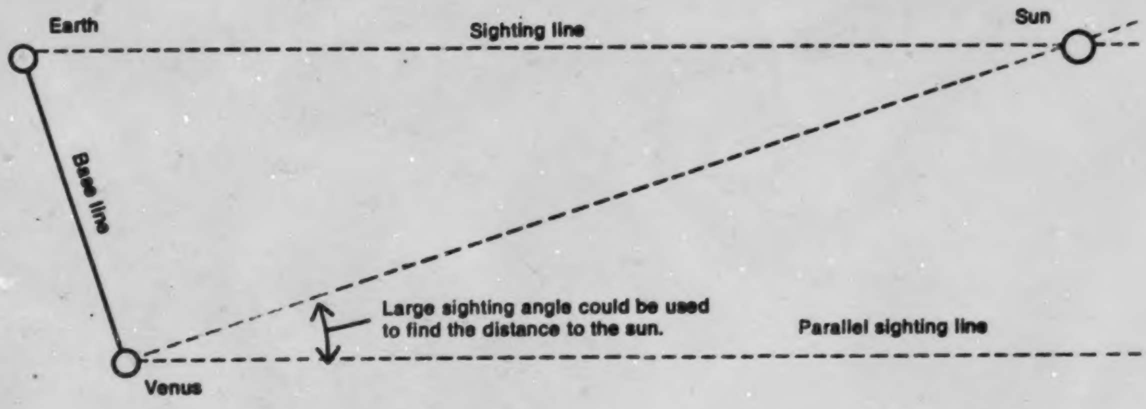
☐**4-1.** Why can't the range finder you used in Chapter 3 measure large distances?

Even the distance across Earth is too small a base for the range-finder method to be used to measure the distance to the sun. But suppose you could use the distance from Earth to Venus as a base line (Figure 4-2).

☐**4-2.** Do you know how long this base line from Earth to Venus is?

☐**4-3.** What other problems would there be in using the scheme diagrammed in Figure 4-2?

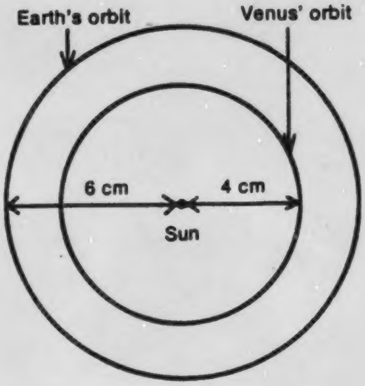
Figure 4-2


Earth
Sighting line
Sun
Base line
Large sighting angle could be used to find the distance to the sun.
Parallel sighting line
Venus

Obviously, you can't easily get to Venus to make a sighting of the sun. This alone makes the plan shown in Figure 4-2 impossible. But there is another way to make use of the distance between Earth and Venus. It requires that you first draw a model of the position of Venus in relation to Earth and the sun. Column 2 of Table 4-1 and the activities that follow will help you do this. Column 1 lists the assumptions you are making as you draw your model.

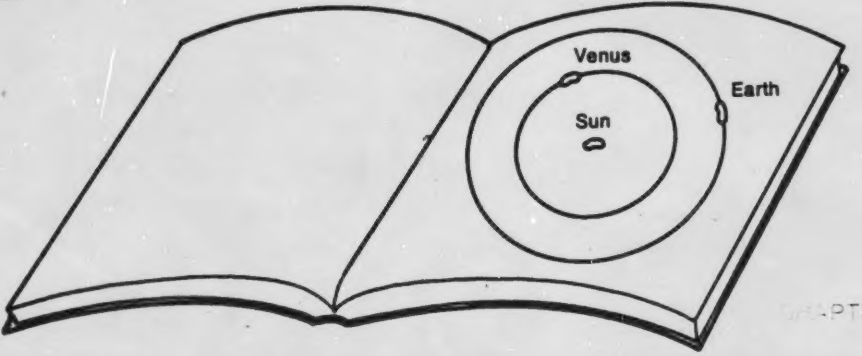
Table 4-1

Assumption	Effect on Drawing
1. The sun is the center of the solar system.	1. Show sun as center of drawing.
2. Earth and Venus are planets revolving around the sun.	2. Venus and Earth can be shown as moving around the center (sun).
3. Venus and Earth move in the same plane.	3. Both Earth and Venus can be drawn on flat paper.
4. Both Venus and Earth move in roughly circular paths (orbits).	4. Show orbits as circles.
5. Venus is closer to the sun than Earth is.	5. Venus' orbit should be drawn smaller than Earth's orbit.



ACTIVITY 4-1. In the space provided in your Record Book, use a compass to draw two circles as shown. Label the sun and the two orbits.

ACTIVITY 4-2. Place a bean anywhere on each of the two circles you've drawn. These will represent Earth and Venus. Place another bean in the center of the circle to represent the sun.



Now, use your model—the beans and circles—to study the relative motions of Venus and Earth. To do this, you will have to add two more assumptions to your list:

1. Earth travels completely around its orbit once every 365¼ days.
2. Venus takes 225 days to make one complete revolution.

☐ **4-4.** Suppose the planet Earth you just placed in orbit made a complete turn around the sun. How far would Venus have traveled in the same time? (Answer by drawing the new position of Venus in Figure 4-3 of your Record Book.)

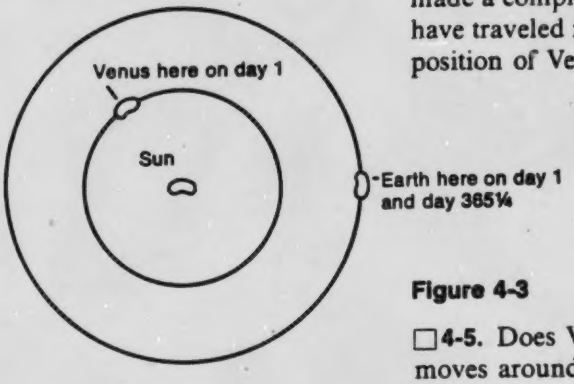
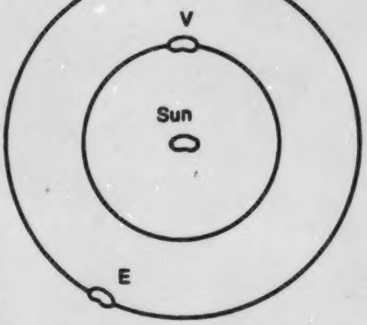


Figure 4-3

☐ **4-5.** Does Venus travel faster, or slower, than Earth as it moves around the sun?

The last activity gives you an idea of what the paths of Venus and Earth are like. Your next problem is to visualize what the motion of Venus would look like from Earth. Once again, your model can help you.

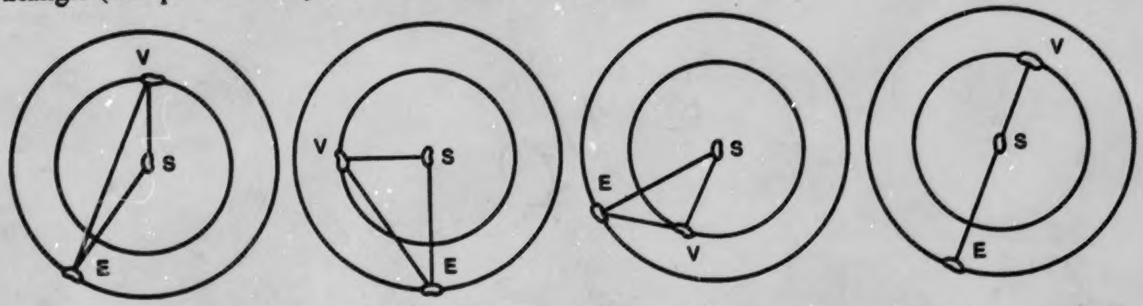
ACTIVITY 4-3. Arrange the beans as shown.



Unless the three beans are perfectly lined up, you can think of them as three points of a triangle.

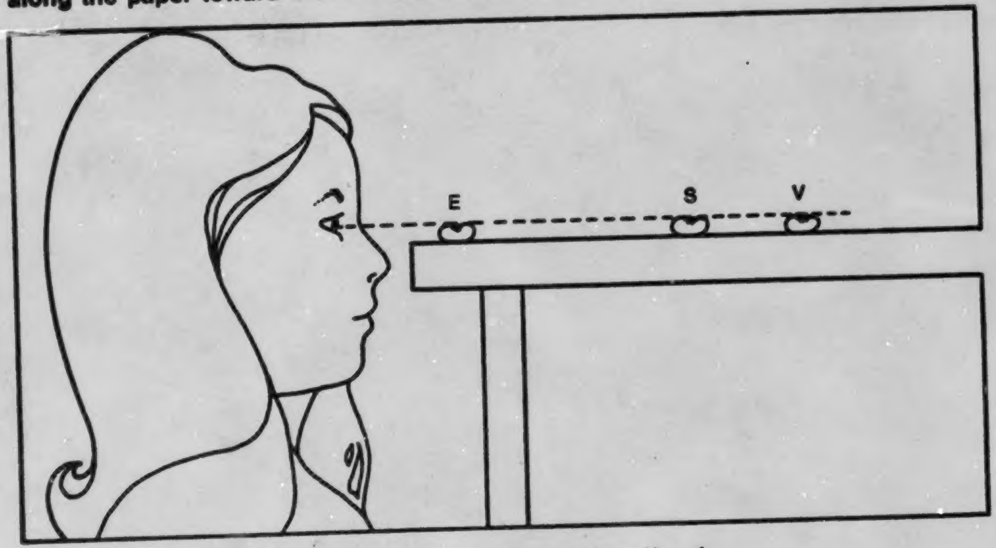
Move Earth and Venus beans to other points along their circular orbits. Notice that the three beans always form a triangle (except when they are lined up). (See Figure 4-4.)

Figure 4-4



Imagine yourself standing on Earth looking at Venus and the sun. Activity 4-4 will help you visualize this.

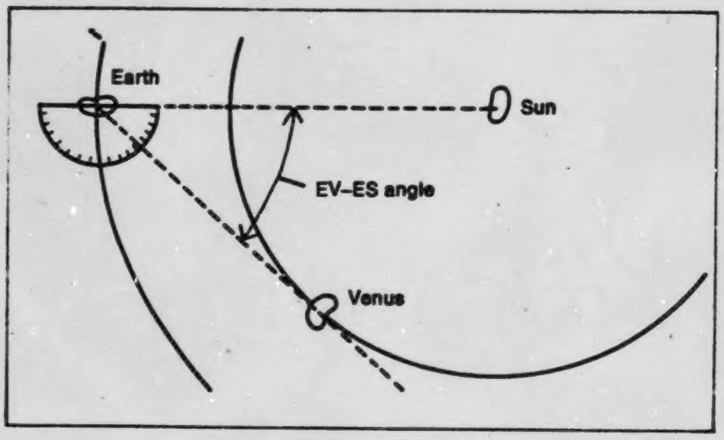
ACTIVITY 4-4. Look from behind the bean representing Earth along the paper toward the sun and Venus.



☐**4-6.** What measurement could you make to describe the position of Venus with respect to the sun?

Question 4-6 may not have been too easy. The angle formed where line EV (the line of sight from Earth to Venus) crosses line ES (the line of sight from Earth to the sun) can be used to describe the position of Venus with respect to the sun.

ACTIVITY 4-5. Experiment by moving Earth and Venus until you find the position at which the EV–ES angle is greatest. Measure this angle with a protractor. (See *Excursion 4-2* if you don't know how to use a protractor.)


Earth
Sun
EV–ES angle
Venus

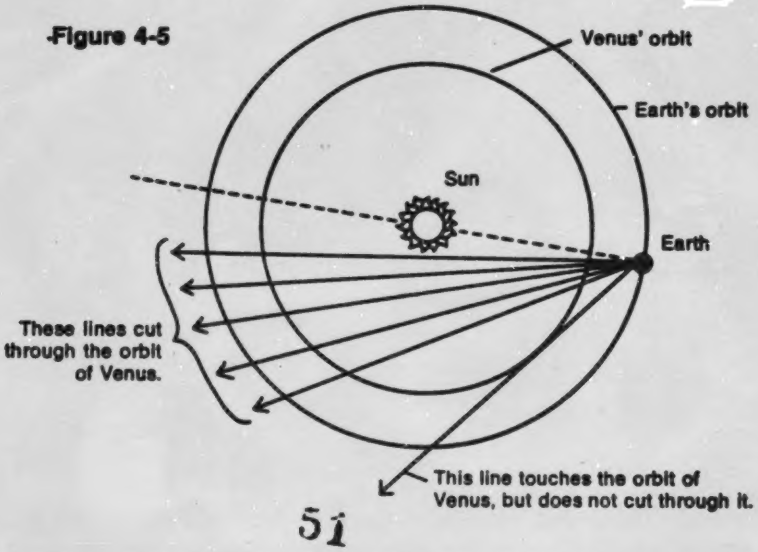
☐**4-7.** When would the EV–ES angle be the greatest?

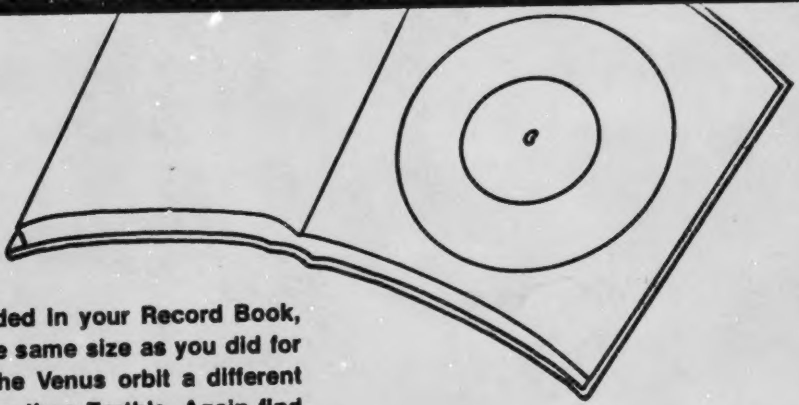
☐**4-8.** What number of degrees are there in the greatest possible EV–ES angle?

☐**4-9.** When would the EV–ES angle be the smallest?

You should have seen that the greatest EV–ES angle occurs when the line of sight from Earth to Venus just touches, but does not cut, the orbit of Venus. (See Figure 4-5.)

Figure 4-5


Venus' orbit
Earth's orbit
Sun
Earth
These lines cut through the orbit of Venus.
This line touches the orbit of Venus, but does not cut through it.

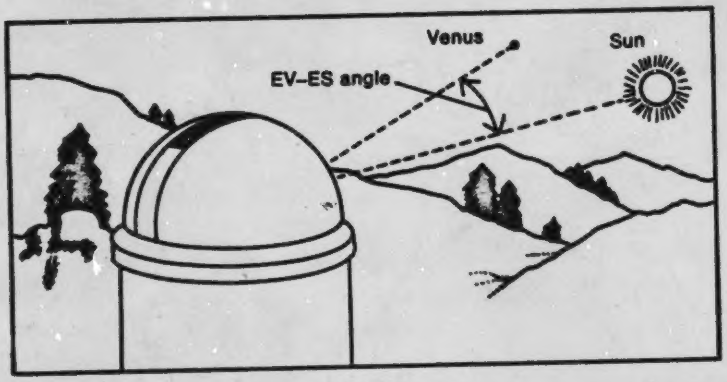


ACTIVITY 4-6. In the space provided in your Record Book, draw a diagram of Earth's orbit the same size as you did for Activity 4-1. But this time, draw the Venus orbit a different size than before, keeping it smaller than Earth's. Again find the greatest EV–ES angle and measure it with a protractor.

☐**4-10.** How many degrees are there in the greatest possible EV–ES angle this time?

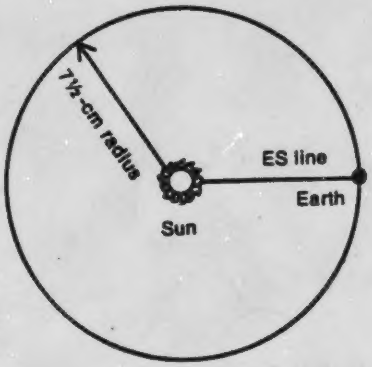
☐**4-11.** Does the greatest EV–ES angle occur again where the Earth–Venus line just touches but does not cross the orbit of Venus?

Figure 4-6

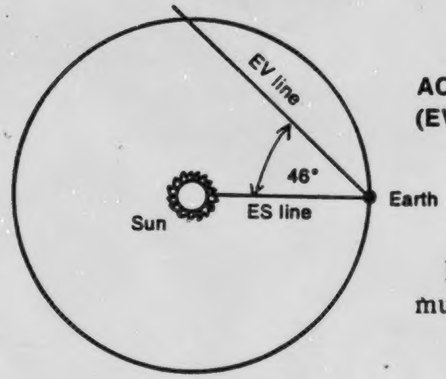


Measuring the real EV–ES angle is easy (see Figure 4-6). Astronomers have found that the average greatest EV–ES angle is 46 degrees. This figure can be used to find the distance from Venus to the sun.

But what does that have to do with measuring the distance from Earth to the sun? That was the question that started this discussion of EV–ES angles.

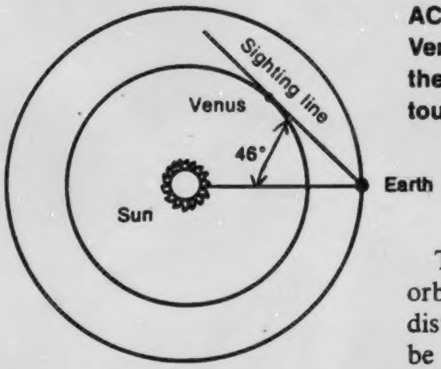


ACTIVITY 4-7. In the space provided in your Record Book, draw a 15-cm diameter circle to represent the orbit of Earth. Draw in an Earth–sun (ES) line as shown.



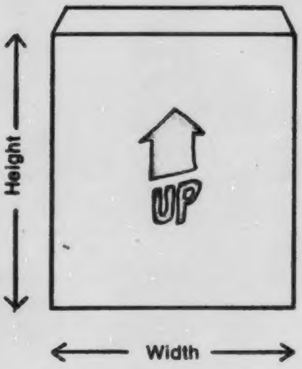
ACTIVITY 4-8. Using your protractor, draw in the Earth–Venus (EV) line for the largest EV–ES angle (46 degrees).

From your earlier work, you know that the orbit of Venus must just touch, but not cut, this **EV** line.



ACTIVITY 4-9. Using a compass, draw the orbit circle for Venus. Remember, the circle should just touch, but not cut, the sighting line. At the exact point where the sighting line touches Venus' orbit, make a small dot and label it "Venus."

The drawing you just made is a scale drawing of the actual orbits of Venus and Earth. It can be used to determine the distance from Earth to the sun. Before you do this, however, be sure you know what a scale drawing is by doing the following checkup.



Scale: 1 cm = 4 ft

CHECKUP

Here is a scale drawing of a packing crate.

1. How high (in feet) was the crate from which the scale drawing was made?
2. How wide (in feet) was the actual crate?

Check your answers to this checkup on page 89 of **Excursion 4-3.**

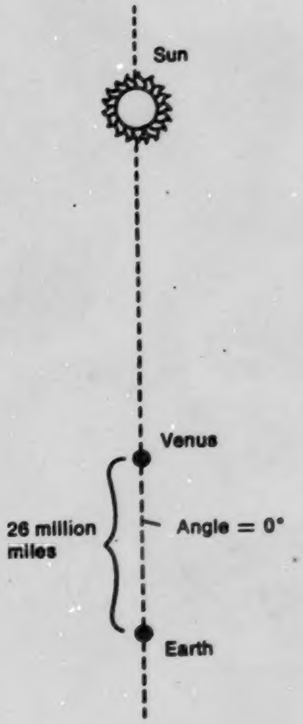
☐**4-12.** Measure on your scale drawing from Activity 4-7 the distance between Earth and Venus when they are closest together. This will be when Earth, Venus, and the sun are lined up, and the **EV–ES** angle is 0 degrees. (See art in margin on the next page.) Record this distance (in mm) on the bottom line of Table 4-2.

The distance you just measured in millimeters represents 26 million miles (see Table 4-2).

☐**4-13.** By your scale, how many miles are represented by each millimeter?

Table 4-2

	On Scale Drawing (mm)	Actual (miles)
Distance from Venus to the sun		
Distance from Earth to the sun		
Smallest distance between Earth and Venus		26 million



☐**4-14.** Using your scale drawing from Activity 4-7, measure (in millimeters) the distance from Venus to the sun and the distance from Earth to the sun. Record your measurements in Table 4-2.

You now have enough information to complete the problem you started at the beginning of Chapter 3. From the data in Table 4-2 and your scale, you can calculate the distance of the sun from Earth and also the distance of the sun from Venus.

☐**4-15.** Calculate the distance in miles from Venus to the sun and from Earth to the sun. Record the results of your calculations in Table 4-2.

A good check on your work is to see if the sum of your actual Venus-to-sun distance and Earth-to-Venus distance equals the Earth-to-sun distance. If the calculations of question 4-15 proved difficult, **Excursion 4-4** will help you.

EXCURSION

If you've done your work well, you now have the information you set out to find at the beginning of Chapter 3. You now know the distance from Earth to the sun. Using methods not too different from yours, astronomers have found the average distance from Earth to the sun to be roughly 93 million miles. Do your results agree?

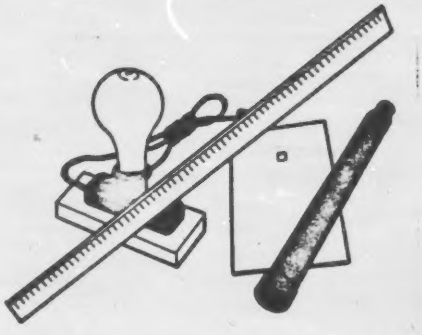
Before going on, do Self-Evaluation 4 in your Record Book.

How Big Is the Sun?

Chapter 5

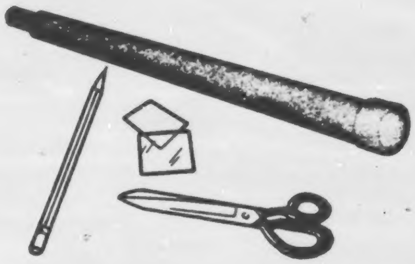
If at first you don't succeed, try, try again. That's the way the old saying goes. Your first try at measuring the distance to the sun wasn't successful. You couldn't get a base line that was long enough to use the range-finder method. So then you tried another approach, using the radar distance to Venus. This time you got the job done.

In this chapter you will try to make another measurement of the sun. This time you will try to find out how far it is across the sun. Obviously, measuring the distance across an object that is 93 million miles away is a bit more complicated



than just laying a ruler next to it. But with a little thought the job can be done fairly easily. To make your measurements, you and a partner will need these materials:

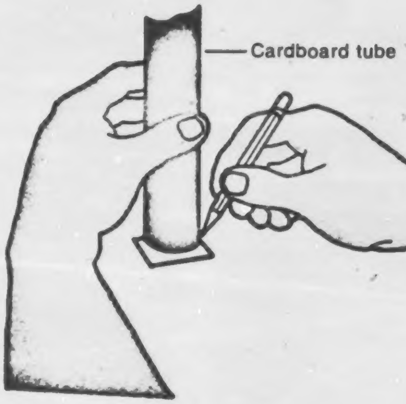
- 1 cardboard sighting scope with frosted acetate screen
- 1 piece cardboard, 13 cm × 20 cm with 1 cm^2 hole
- 1 150-watt bulb and socket
- 1 meterstick

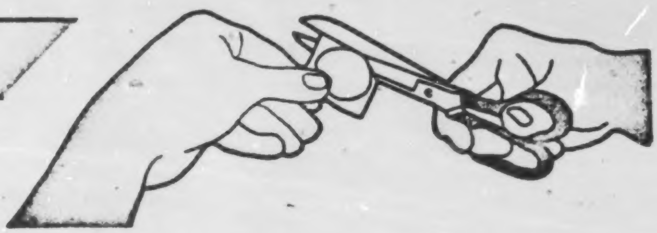


If the sighting scope has not been assembled, Activities 5-1 through 5-4 show you how to construct the sighting scope. To do this, you will need:

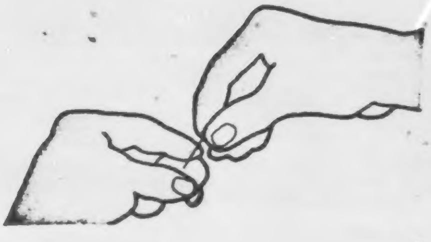
- 1 telescoping cardboard tube, 40 cm long with end caps
- 1 piece of thin cardboard, 4 cm^2
- 1 piece frosted acetate, 4 cm^2
- 1 pair scissors
- 1 sharp pencil

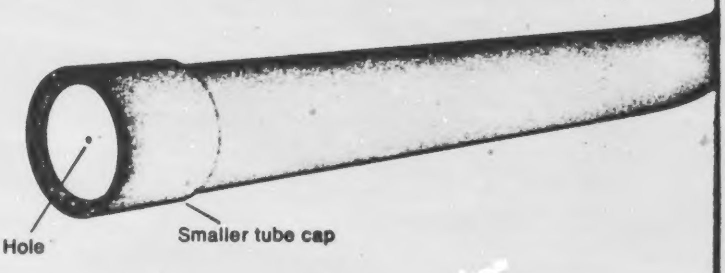
ACTIVITY 5-1. Remove the smaller cap from the cardboard tube. With a sharp pencil, trace the outside of the tube on the 4 cm × 4 cm piece of cardboard. Cut along the lines to form a disk.





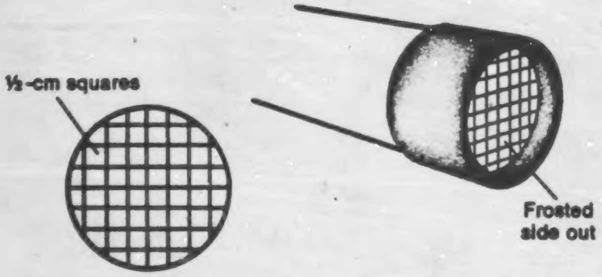
ACTIVITY 5-2. Make a smooth pinhole in the center of the cardboard disk with a large needle or pin. Place this disk in the cap and replace the cap on the tube.





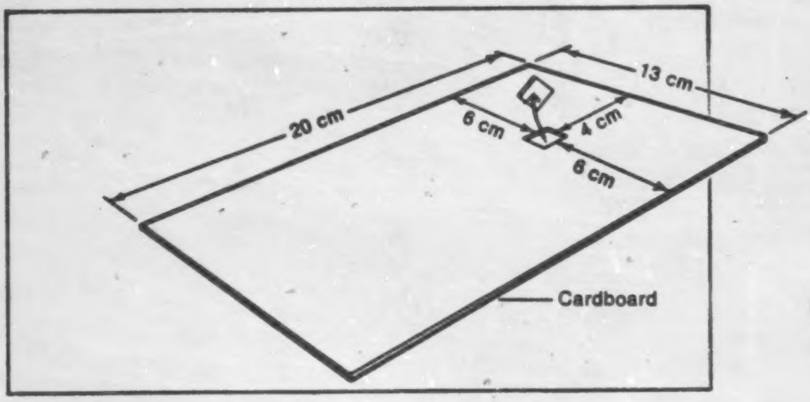
Prepare an acetate disk to fit in the larger cap.

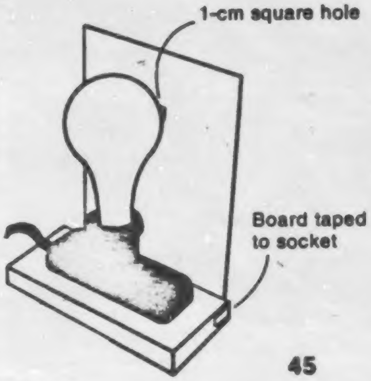
ACTIVITY 5-3. Be sure you use a well-sharpened pencil to mark off 1/2-cm squares on the frosted side of the acetate disk. This must be carefully done. Place this disk in the tube cap, with the frosted side out. (Your frosted acetate disk, by the addition of the grid lines, has been made into what is commonly called a screen.)



If the cardboard (13 cm × 20 cm) with the 1 cm^2 hole is available, skip to Activity 5-5.

ACTIVITY 5-4. Mark off a 1-cm square on a 13- × 20-cm cardboard sheet in the position shown. *Place it on something flat that can be used as a cutting surface.* With a razor blade, remove the square, leaving a hole in the cardboard.

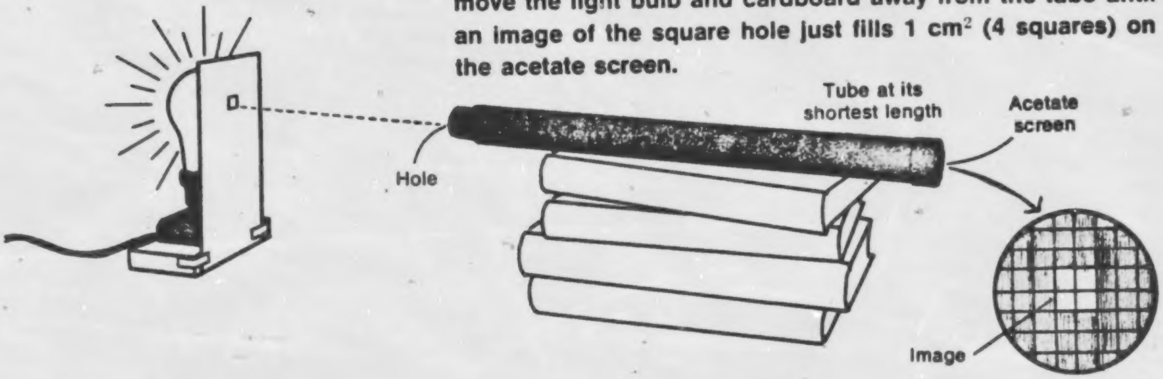




ACTIVITY 5-5. Tape the 13- × 20-cm cardboard in front of the light bulb as shown. Be sure the brightest part of the bulb is lined up with the square hole.

For what follows, you will need a level space behind the bulb of up to 3 ft and about 2 ft in front of the bulb.

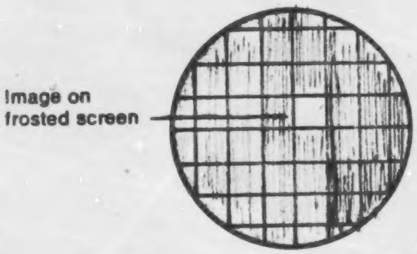
ACTIVITY 5-6. Support the tube on books so that it is level and pointing straight at the square hole. Have the tube at its shortest length (small tube pushed in all the way). Gradually move the light bulb and cardboard away from the tube until an image of the square hole just fills 1 cm^2 (4 squares) on the acetate screen.



☐**5-1.** What is the distance (in cm) from the pinhole to the square hole in the card?

☐**5-2.** What is the distance (in cm) from the pinhole to the screen (the length of the cardboard tube)?

Figure 5-1



If you have made careful measurements, you should have found the distance from the pinhole to the screen to be about the same as the distance from the pinhole to the square hole in the card.

Now move the cardboard with the square hole away from the pinhole until only one square on the screen is filled with the image. (See Figure 5-1.)

☐**5-3.** Now what is the distance (in cm) from the pinhole to the square hole?

The new distance you just measured should be about twice the distance from the pinhole to the screen.

☐**5-4.** How many times bigger is the distance across the square hole in the cardboard (1 cm) than the distance across the image ($\frac{1}{2}$ cm)?

Perhaps you are beginning to see some relationships here. The distance from the pinhole to the screen and the size of the image that forms are related. Although you may not see how as yet, you can use this relationship to measure the size of a bright object such as the 150-watt bulb. Let's see how this can be done.

Here's the relationship you need.

$$\text{Distance across the object} = \frac{\text{Distance from the object to the pinhole}}{\text{Distance from the pinhole to the screen}} \times \text{distance across the image}$$

Here's an example of how the relationship can be used.

The distance from the pinhole to the square hole in the cardboard is 84 cm. The distance from the pinhole to the screen (the length of the tube) is about 42 cm. The width of the image on the screen is ½ cm. All of this is shown in Figure 5-2.

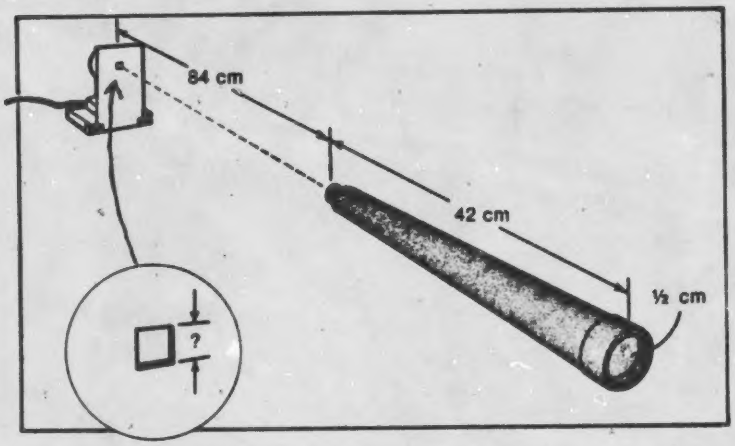


Figure 5-2

$$\begin{aligned}\text{Distance across the square hole} &= \frac{84\text{ cm}}{42\text{ cm}} \times \text{distance across the image}\\ &= \frac{84\text{ cm}}{42\text{ cm}} \times \tfrac{1}{2}\text{ cm}\\ &= 2 \times \tfrac{1}{2}\text{ cm}\\ &= 1\text{ cm}\end{aligned}$$

Now check to be sure that your answers to questions 5-1, 5-2, 5-3, and 5-4 fit the relationship. For example, in order for your answers to 5-1 and 5-2 to fit, they must be equal. This is because the object and image width are the same size at that setting.

Figure 5-3B shows how you can calculate the distance across the sun in the same way that you just calculated the distance across the hole in the cardboard (Figure 5-3A). All you need do is set up the sighting scope so that the pinhole faces the sun. When the scope is lined up, the sun's image will fall on the screen.

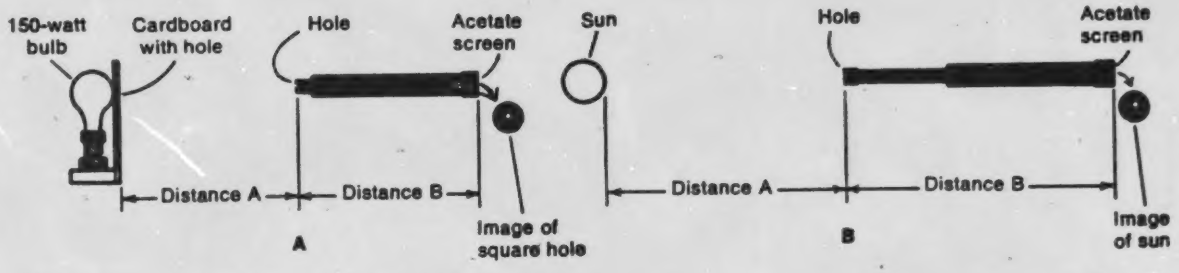

150-watt bulb
Cardboard with hole
Hole
Acetate screen
Distance A
Distance B
A
Image of square hole
Sun
Hole
Acetate screen
Distance A
Distance B
B
Image of sun

Figure 5-3

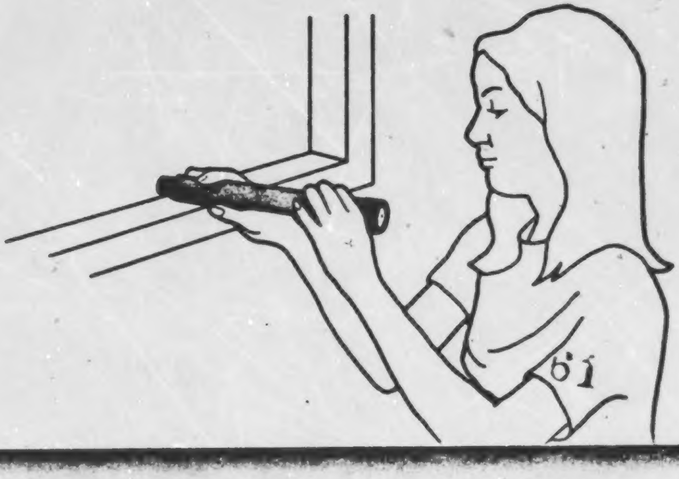
Safety Note *Remember, you should never look directly at the sun.*

Once you've formed an image of the sun, you can get everything needed to calculate the distance across the sun by using the relationship. You've already measured the distance from the sun to the pinhole—93 million miles. Thus:

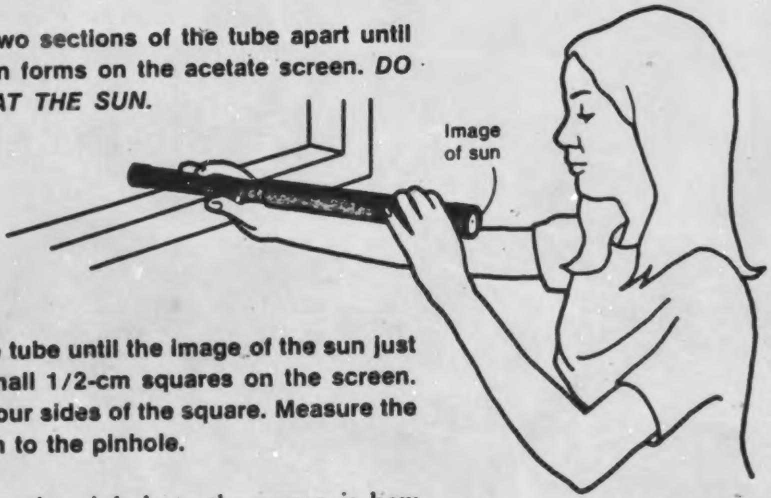
$$\text{Distance across the sun} = \frac{93{,}000{,}000 \text{ miles}}{\text{Distance from pinhole to screen}} \times \text{distance across the image}$$

Now you need to measure the width of the image on the screen.

ACTIVITY 5-7. Point the pinhole end of the tube directly at the sun as shown.



ACTIVITY 5-8. Pull the two sections of the tube apart until a *sharp* image of the sun forms on the acetate screen. *DO NOT LOOK DIRECTLY AT THE SUN.*

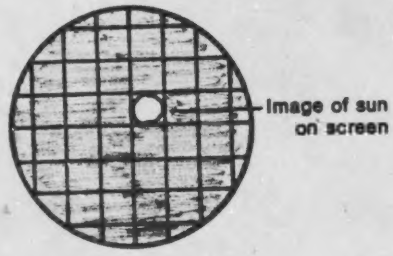


ACTIVITY 5-9. Adjust the tube until the image of the sun just fits inside one of the small 1/2-cm squares on the screen. It should just touch the four sides of the square. Measure the distance from the screen to the pinhole.

☐**5-5.** The distance from the pinhole to the screen is how many cm?

Now you have all the data that you need to calculate the distance across the sun by using the relationship.

$$\text{Distance across the sun} = \frac{93{,}000{,}000 \text{ miles}}{\text{Distance from pinhole to screen in cm}} \times \tfrac{1}{2} \text{ cm}$$



☐**5-6.** What is the distance across the sun in miles? (If you make the calculation shown above, your answer will automatically come out in miles because the centimeters cancel out.)

You may have been surprised to learn how large the sun really is. Its diameter is greater in length than the diameter of the moon's orbit around the earth. More importantly, though, you should be beginning to realize that with careful thinking and a few measurements and calculations, astronomers can provide answers that at first seem almost impossible to get.

If you would like to make your own telescope and get a good look at the moon, do **Excursion 5-1.**

Before going on, do Self-Evaluation 5 in your Record Book.

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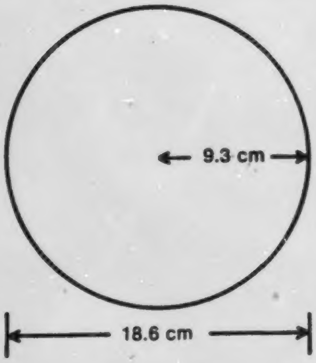
The Fiery Chariot

Chapter 6

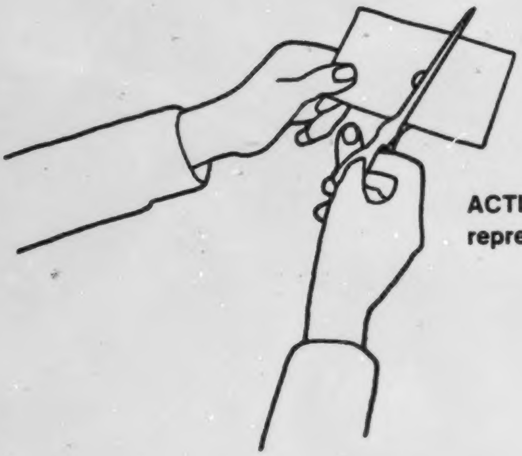
One of the myths told in ancient times described the sun as a flaming ball carried across the sky in a chariot drawn by four horses. Since you formed an image of the sun on a screen in Chapter 5, you know that part of the myth is in fact true—the sun is a flaming ball.

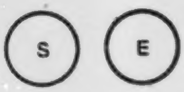
But does the sun move across the sky? To you, the answer is probably a solid No because you know that the earth's turning is what makes the sun appear to move. You may also know that proving this is not so easy. To someone standing on the earth, the sun moving around an unmoving earth would appear the same as the sun standing still with the earth turning. A simple model can show you why.



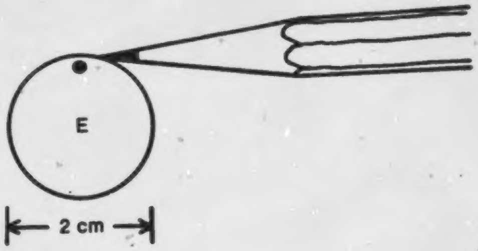
ACTIVITY 6-1. In the space provided in your Record Book, draw a circle 18.6 cm across. In other words, the circle has a radius of 9.3 cm, or 93 mm.

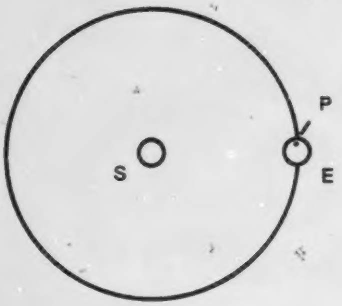
ACTIVITY 6-2. Cut out two cardboard circles about 2 cm across. Label one "S," for the sun, and the other "E," for the earth.





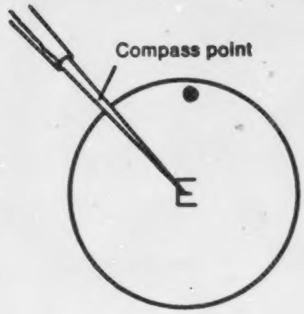
ACTIVITY 6-3. Make a small dot at the edge of the earth. This represents a person standing on the earth's surface.





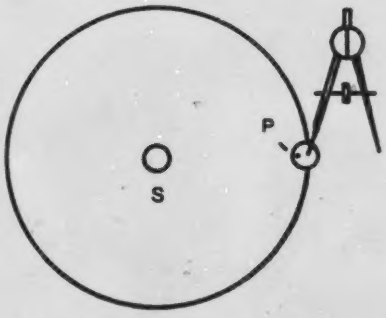
ACTIVITY 6-4. Place the sun in the center of the circle you drew in your Record Book. Then place the earth on the circle as shown. Be sure that the "person dot" is in the position shown.

ACTIVITY 6-5. Stick the point of your compass through the center of the earth. You can think of this point as the North Pole.



☐**6-1.** If you were the person standing on the earth in Activity 6-4, would the sun appear to be overhead or on the horizon?

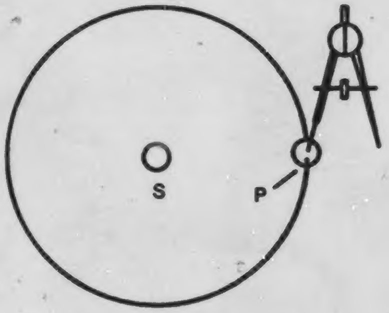
ACTIVITY 6-6. Turn the earth around the compass point to the position shown.



☐**6-2.** Would the sun appear to be overhead to a person standing at the dot?

☐**6-3.** How many degrees did you have to turn the earth to get the sun overhead? (Hint: If you have trouble with this question, see **Excursion 4-2.**)

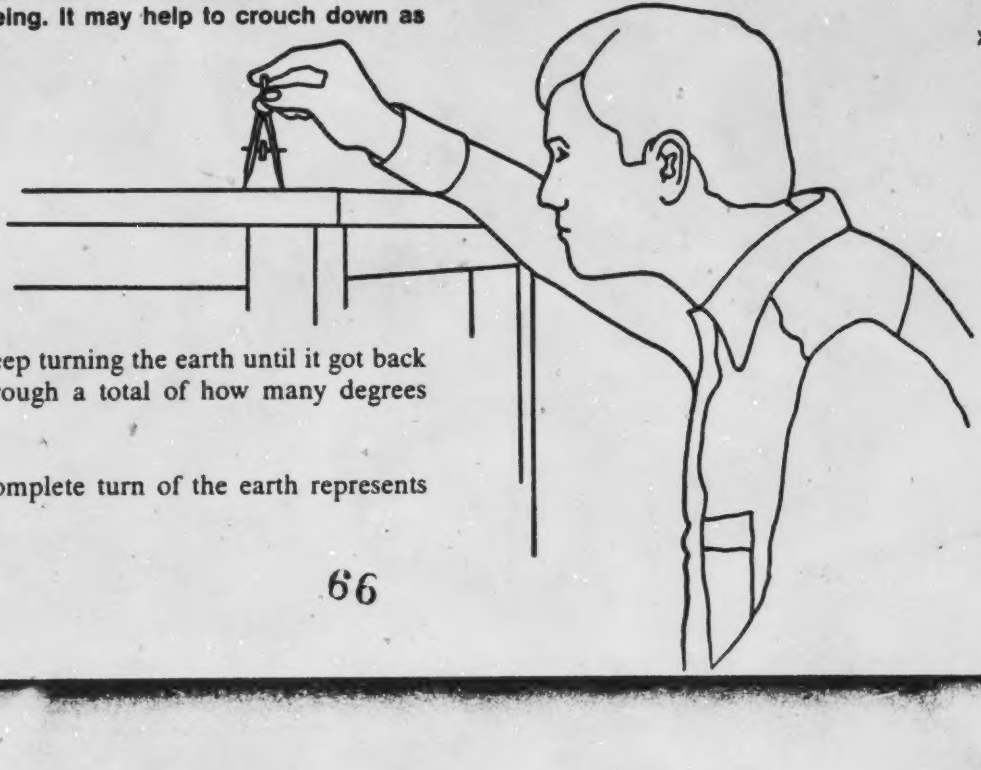
ACTIVITY 6-7. Keep turning the earth until it gets to the place where, to a person at the dot, the sun would again appear to be on the horizon.



☐**6-4.** Now how many degrees have you turned the earth from where it started (in Activity 6-5)?

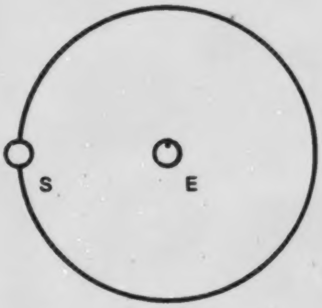
☐**6-5.** If you had been standing on the earth at the dot, would the sun seem to have traveled across the sky from one horizon to the other?

ACTIVITY 6-8. Check your answer to question 6-5 by repeating Activities 6-6 and 6-7. Try to visualize what a person standing at the dot would be seeing. It may help to crouch down as shown.



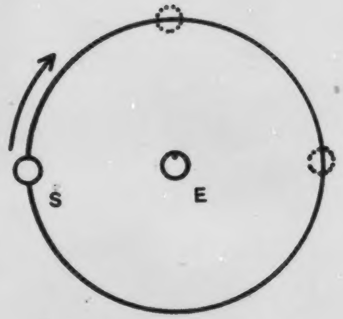
☐**6-6.** If you were to keep turning the earth until it got back to where it started, through a total of how many degrees would it have turned?

As you know, one complete turn of the earth represents one day, or 24 hours.



ACTIVITY 6-9. Now reverse the positions of the earth and the sun on the circle. Be sure that the "person dot" faces upward as shown.

☐**6-7.** With the earth and the sun in the position shown in Activity 6-9, would the person see the sun overhead, or on the horizon?



ACTIVITY 6-10. Move the sun along the circle to a point where it would appear to be overhead to the person. Then continue to move the sun to a point where it would appear to be on the horizon.

☐**6-8.** How many degrees did you move the sun to make it appear overhead to a person at the dot?

☐**6-9.** How many degrees did you have to move the sun to make it appear to move from one horizon to the other?

Now think about what a person at the dot would have seen in the case of the earth turning, and in the case of the sun moving around the earth. In both cases, the sun would appear to move around the earth. In both cases, the sun would appear to rise from one horizon and to set behind the other!

PROBLEM BREAK 6-1

How good an observer are you? You can tell by the answer you give to this question: Is the apparent path of the sun across the sky the same every day?

Of course, the sun doesn't leave a trail in the sky so that you can see any change in path. But there should be some way that you could observe a change if there is any. In your Record Book, describe an observation that you could make with simple apparatus that would show conclusively whether the apparent path of the sun across the sky is the same every day. If you decide that the path changes, give a short explanation of why this is so.

As was said earlier, it isn't so easy to prove that the earth is turning rather than the sun moving around it. Suppose the sun actually does move around the earth while the earth stands still. Because it is far away, it would have to make a very long journey each day. It would have to travel very fast to make it in just 24 hours. You can get a good idea of the speed it must have to make the trip. You only need a few simple things. But you will have to have an hour of sunlight.

If you don't have a full hour ahead of you in this class, read ahead to see what has to be done. Then plan a time when you can do the activity. If you have some spare time now, this would be a good time to do **Excursion 6-1** and find out about "The Night That People Lost 10 Days." No equipment is needed.

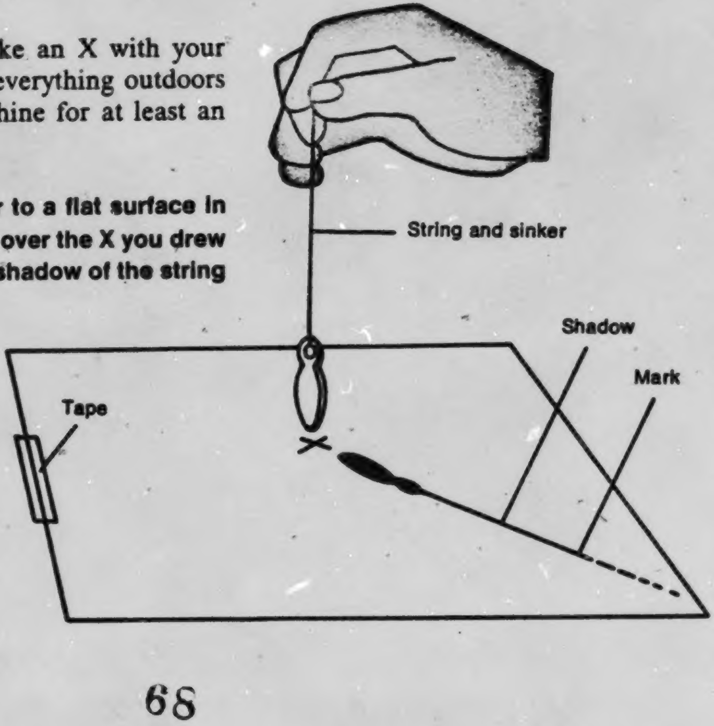
EXCURSION

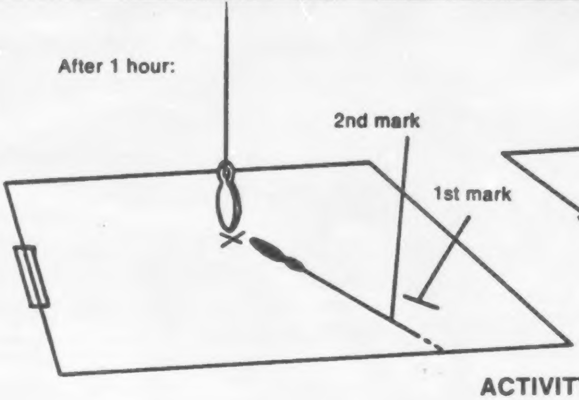
Got a sunny day and a full hour? Then let's find out how fast the sun would have to be to go around the earth each day. Get the following items:

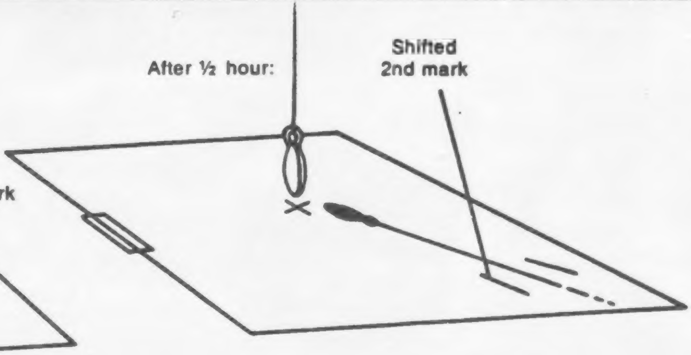
1 lead sinker
1 50-cm piece of string
1 protractor
1 2-inch piece of masking tape or cellophane tape
1 sheet of white paper

Tie the string to the lead sinker. Make an X with your pencil in the center of the paper. Take everything outdoors or to a windowsill where the sun will shine for at least an hour.

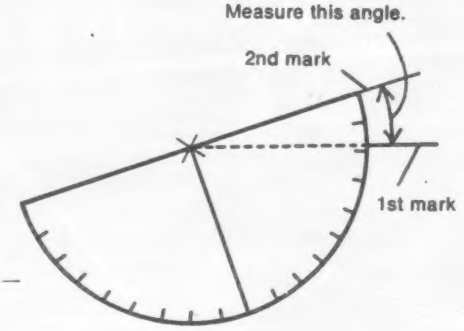
ACTIVITY 6-11. Tape your piece of paper to a flat surface in full sunlight. Then hold the sinker *exactly* over the X you drew on the paper. Draw a short line along the shadow of the string on the paper. Jot down the exact time.




After 1 hour:
2nd mark
1st mark


After ½ hour:
Shifted 2nd mark

ACTIVITY 6-12. *Exactly one hour later,* hold the string as you did before, and once again mark the shadow. (Note: If you do not have a full hour available, use 1/2 hour and double the distance of the 2nd mark from the 1st mark.)


Measure this angle.
2nd mark
1st mark

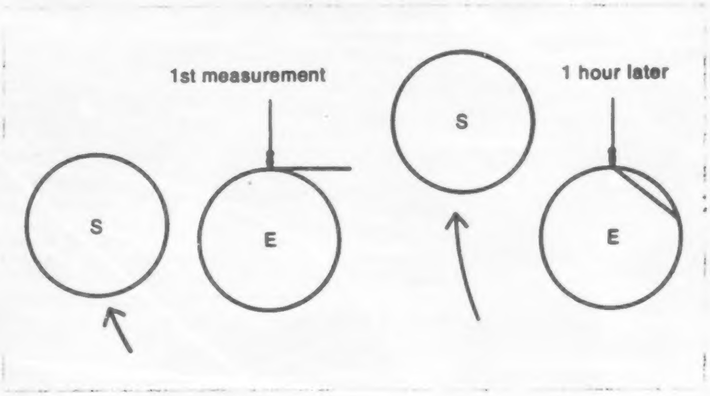
ACTIVITY 6-13. Take your paper back to your desk. With a ruler, draw straight lines from the X along each of the shadow marks. Measure the angle between the lines with a protractor.

☐**6-10.** How many degrees are in the angle formed by the two shadow lines?

Now try to apply what you have just done to the model you built earlier. Figure 6-1 diagrams what would have happened if the person standing at the dot in Activity 6-10 had been holding a sinker as you did.

Notice in Figure 6-1 that as the sun moves, the shadow of the string moves too. This suggests that measuring the distance that the shadow moves in a given time could tell you how fast the sun would have to move. Let's find out if it will.

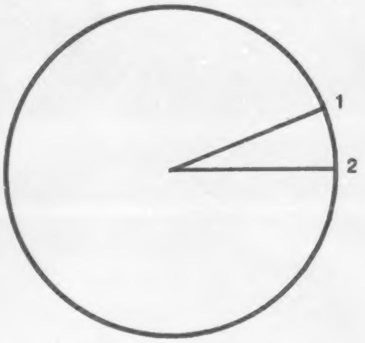
Figure 6-1


1st measurement
S
E
1 hour later
S
E

In Activity 6-1 you drew a circle with a radius of 93 mm. This size was chosen to make your next set of calculations easy. Think of a distance of 93 mm as representing the distance of 93 million miles from the earth to the sun.

☐**6-11.** How many miles does each mm represent?

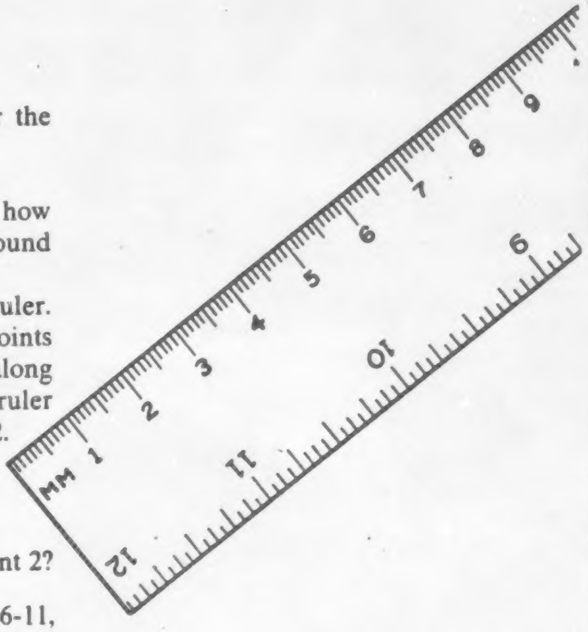
ACTIVITY 6-14. On the circle you drew in your Record Book, draw an angle like the one you measured in Activity 6-13. Use your protractor and a sharp pencil. Label the angle as shown.



☐**6-12.** The distance between 1 and 2 shows how far the sun appears to travel in how long?

Using the distance between 1 and 2, you can calculate how far the sun would have to travel in one hour if it goes around the earth in one day.

You can't measure a curved line accurately with your ruler. But when the angle is small, the distance between two points along a curve is not too different from the distance along a straight line. This means that you can use a millimeter ruler to get a good estimate of the distance between 1 and 2.



☐**6-13.** What is the distance in mm from point 1 to point 2?

☐**6-14.** Using the scale you determined in question 6-11, what is the distance in miles that the sun would have had to travel?

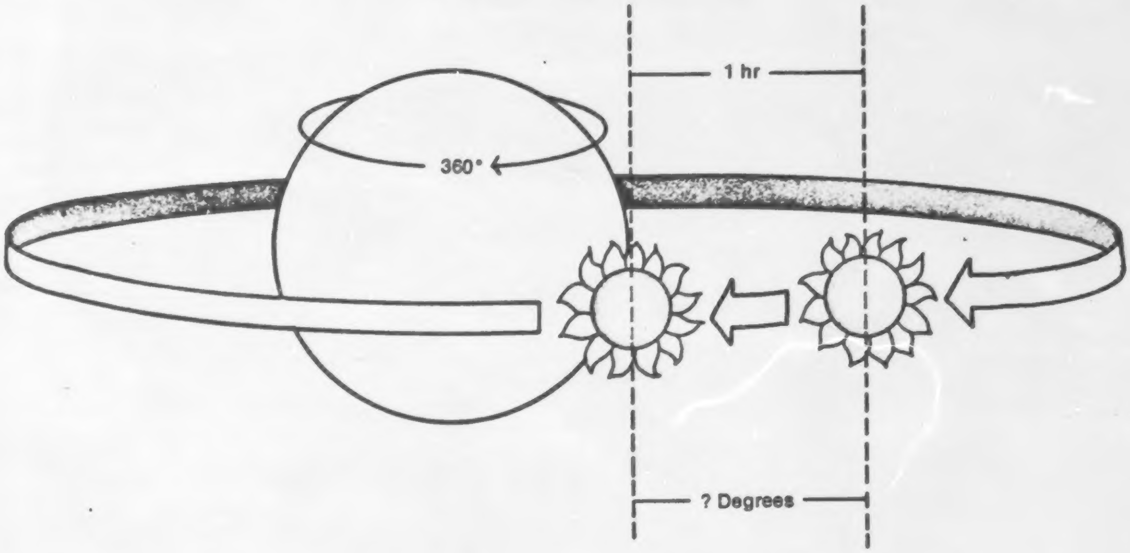
☐**6-15.** What would its speed in miles per hour have to be?

Your answer to question 6-15 should be a very large number. In fact, the speed is many, many times greater than that of any satellite ever put into orbit. And it is far greater than the calculated speed of other planets and most stars. Therefore, the model that the sun moves around the earth each day is very unlikely.

☐**6-16.** Can you think of a way to calculate how fast the earth is turning? (Hint: The distance around the earth is 25,000 miles.)

PROBLEM BREAK 6-2

You know that the apparent rising and setting of the sun is caused by the earth's making one complete turn on its axis in 24 hours. You know that there are 360 degrees in a circle, or in one turn of the earth. Using this information, you can figure the number of degrees that the sun appears to travel in one hour.



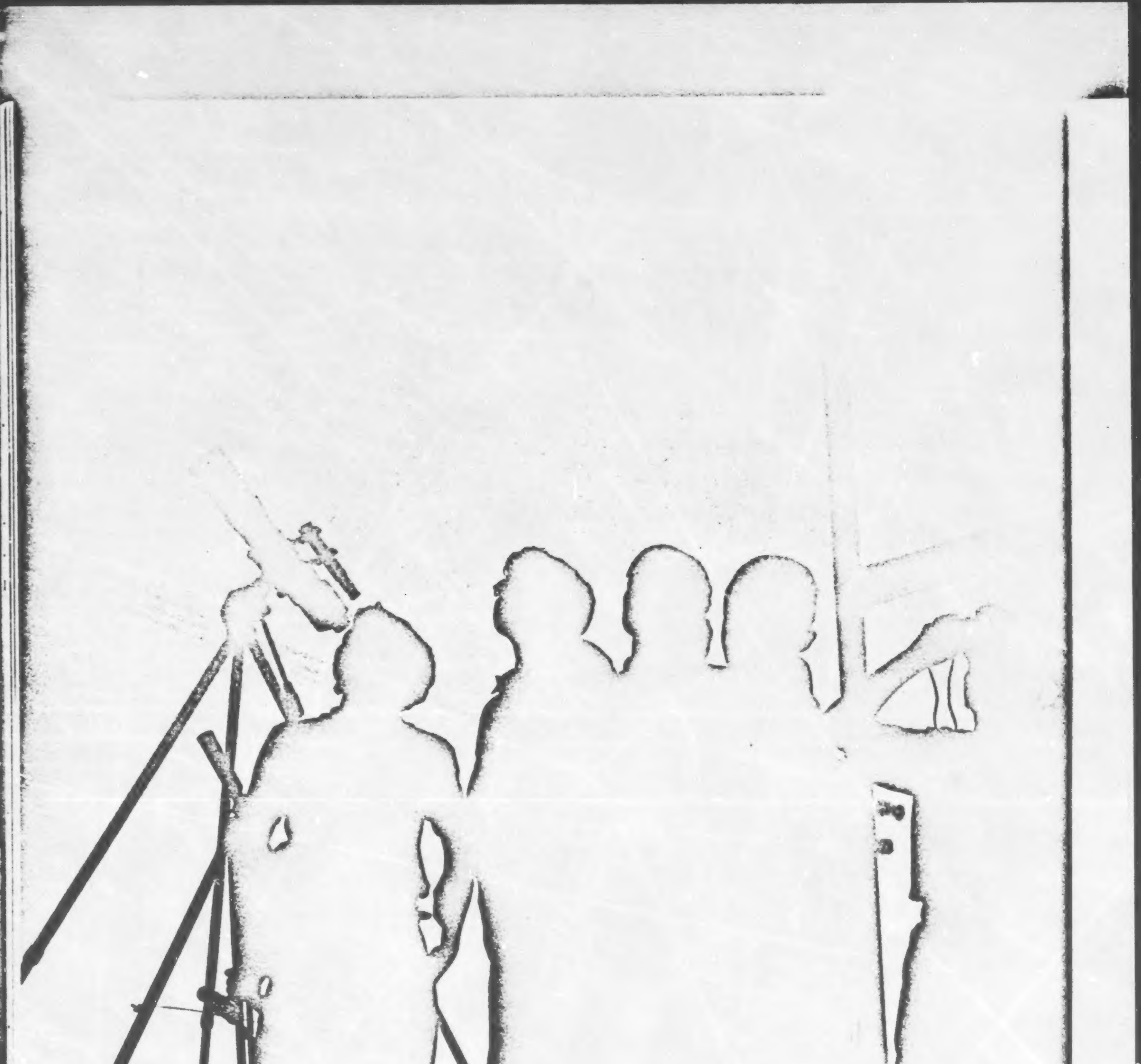
What is the relationship between the number of degrees that the sun travels in one hour and the time zones that we use? For example, why is the time in New York different from the time in Chicago, and the time in Denver different from the time in Los Angeles? Write your explanation in your Record Book.

You have seen that your daily observations of the sun do not tell you whether it, or the earth, is moving. Because you've been told, you know that the earth is turning—the movement of the sun is just an illusion. Even so, it is more comfortable to say that the sun is "rising" or "setting" than to say the earth is turning. It feels quite natural and okay to say the sun moves across the sky.

Many scientists of old thought man lived in a sun-centered system. Others claimed that the universe was earth-centered. To find out how Galileo resolved this debate, do **Excursion 6-2.**

EXCURSION

Before going on, do Self-Evaluation 6 in your Record Book.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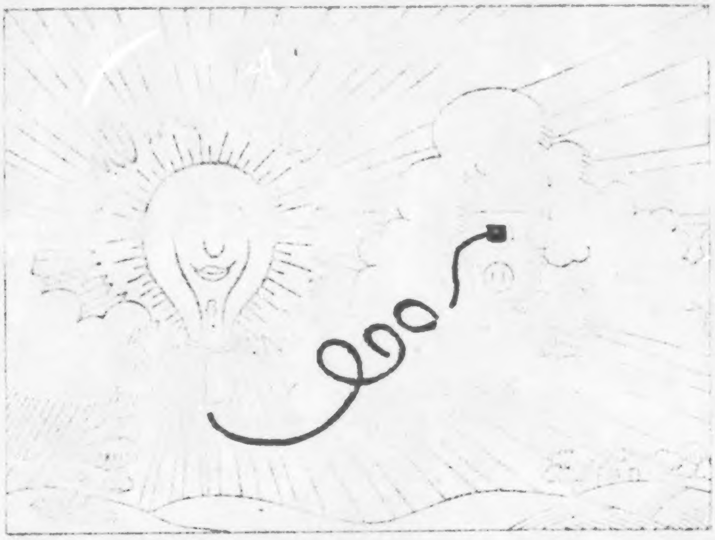
On Your Own

Chapter 7

At the beginning of this unit, you set out to investigate the way astronomers get information about celestial objects. You now should have a pretty good idea of the way they work. By using sun-energy measurers (pyrheliometers) and photographs of spectra, and by calculating angles, astronomers can make quite remarkable measurements.

In this last chapter you will be given a chance to apply a few of the astronomers' techniques on your own. Your first investigation will help you wrap up your study of the sun.

Back in Chapter 2 you learned that the sun produces the same effect on your sun-energy measurer as does a 50-watt bulb held a few centimeters from it. However, you never really found out how many watts of power the sun has.

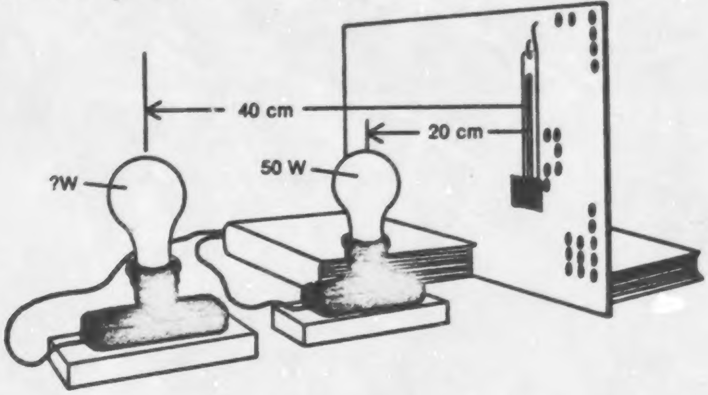


To see how you can measure its power, you need to think of the sun as a great big light bulb 93,000,000 miles from the earth. To figure out how many watts that big sun bulb has, you need to know an important relationship. You need to know how distance affects the amount of light coming from a far object. You have a big clue to that relationship from Chapter 2. (Do you know what power is? Look over **Excursion 7-1.**)

EXCURSION

In Activity 2-12, you found out the effect of a 50-watt bulb on your pyrheliometer. You placed the bulb 20 cm from the pyrheliometer and observed a certain temperature change. In Activity 2-13, you moved the light socket to a distance of 40 cm from the pyrheliometer. You then found out how many watts were needed to produce the same effect that had been caused by the 50-watt bulb at 20 cm.

☐**7-1.** How many watts at 40 cm produced the same effect on your sun-energy measurer as did a 50-watt bulb at 20 cm? (See your answer to question 2-21.)



☐**7-2.** When you double the distance from the pyrheliometer to the light source, what must you do to the total wattage of the bulb to keep the sun-energy measurer reading the same?

If you did your arithmetic well, you now know how increasing distance affects the amount of light coming from a source. When the distance from an object to a light source is doubled, the power of the light source must be four times greater if the same amount of light is to reach the object. (See Figure 7-1.)

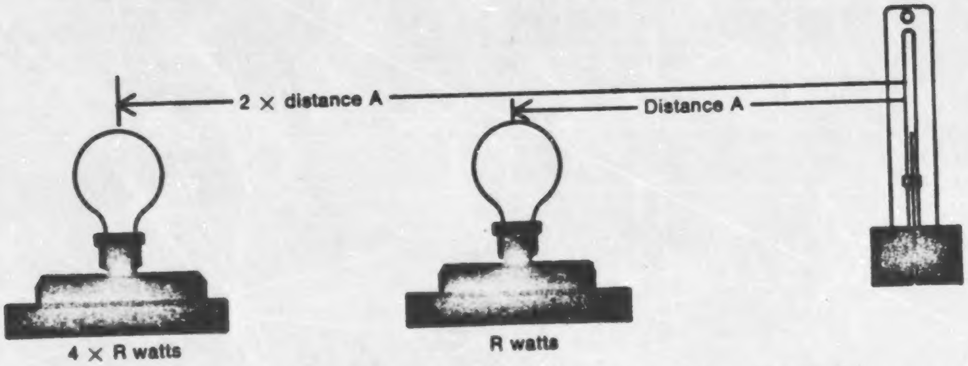


Figure 7-1

This relationship plus your earlier data is all that you need to know in order to measure the wattage of the sun. Table 7-1 suggests one way to do this.

Table 7-1

Measured Distance (Sample)	Wattage
10 cm	50
20 cm	200
40 cm	800
80 cm	3,200
160 cm	12,800
⋮	⋮
93 million miles	.

The person who made Table 7-1 simply kept doubling the distance an imaginary bulb was from a sun-energy measurer. To keep the light received the same each time, he kept multiplying the wattage of the bulb by 4. If he were to keep doing this until the distance became 93 million miles (15,000,000,000,000 cm), he would have found the wattage of the sun.

If you have a lot of time to spare, you might like to try the approach taken in Table 7-1. Another way to do the same thing is described in **Excursion 7-2,** "Using Squares to Measure Distance." Although shorter, it involves slightly more-difficult mathematics. Use one of these two methods to calculate the sun's power in watts. If you decide to use the longer method described in Table 7-1, you may find the following check list helpful.

EXCURSION

1. Make two columns on a sheet of lined paper.
2. Label the left-hand column "Distance" and the right-hand column "Wattage."

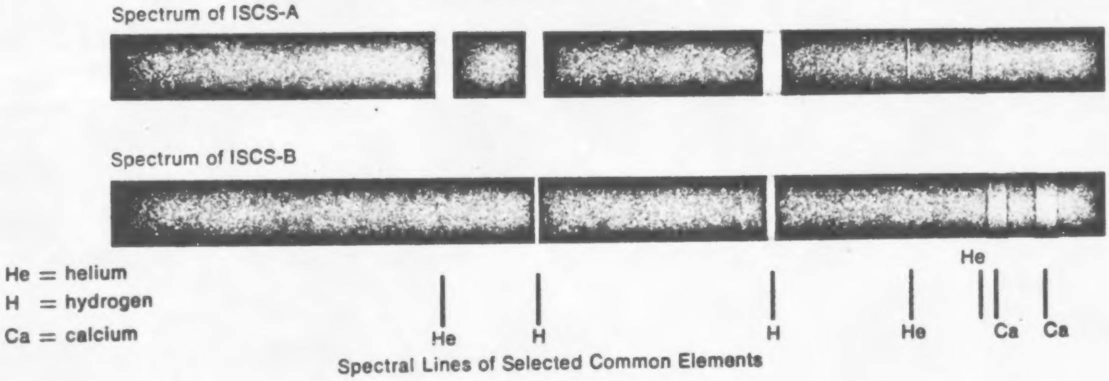
3. At the top of the left column, write in the distance in cm from question 2-18 of Chapter 2. Opposite this number, in the right-hand column, write in 50 Watts.
4. Double the distance in the left-hand column and write the new distance under the first. Multiply the 50 W in the right-hand column by 4, and write the new wattage (200) under the 50.
5. Keep doubling the distance number in the left-hand column. Each time, multiply the wattage number in the right-hand column by 4.
6. Continue doubling the left-hand numbers until you reach 15,000,000,000,000 cm. In each case, multiply the number in the right-hand column by 4.
7. The last number in the right-hand column, opposite 15,000,000,000,000 cm, is the estimated wattage of the sun.

☐ **7-3.** What is the wattage of the sun?

Now you should test your ability to use some of the other techniques you have learned. For the first exercise, you will be given spectroscope data for two stars, ISCS-A and ISCS-B. Your task is to interpret this information to find out as much as you can about the stars. From it, you should be able to say something of the way the two stars compare in composition, distance, and power.

Figure 7-2 shows the spectra observed when the light from ISCS-A and ISCS-B passed through a spectroscope. It also shows the spectral lines of some common elements. Look at the spectra carefully. They and Tables 7-2 and 7-3 contain all the information you need to finish this first exercise.

Figure 7-2


Spectrum of ISCS-A

Spectrum of ISCS-B

He = helium
H = hydrogen
Ca = calcium

Spectral Lines of Selected Common Elements

Table 7-2

Distance from the Earth

ISCS-A	50,000,000,000,000 miles, or 8,000,000,000,000,000,000 cm
ISCS-B	25,000,000,000,000 miles, or 4,000,000,000,000,000,000 cm

Table 7-3

Energy Data

	Sun-Energy Measurer Reading
ISCS-A	19.9° C
ISCS-B	34.6° C
Reading in shade	5.2° C

☐**7-4.** In your Record Book, record your conclusions about the two stars. Then give a brief explanation of the way you reached the conclusions.

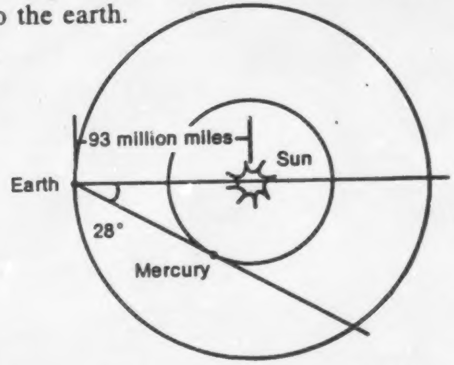
Your written discussion should include a comparison of the two stars in terms of their power and the elements they contain. Try to get other information about the two stars if you can. You will probably want to review Chapters 1, 2, and 7 as you do this activity.

MEASURING THE DISTANCE TO MERCURY

Your next problem is to determine the shortest distance from the earth to the planet Mercury. You can use a procedure similar to that used in Chapter 4 to find the distance to the sun. You may assume that the earth and Mercury both move around the sun in circular orbits. You know that the earth is approximately 93 million miles from the sun, and that the maximum sun-earth-Mercury angle is 28°. Figure 7-3 illustrates this. With it and the data given, you should be able to solve the problem. Make your observations and record your findings in your Record Book.

☐**7-5.** Record your calculation of the shortest distance from Mercury to the earth.

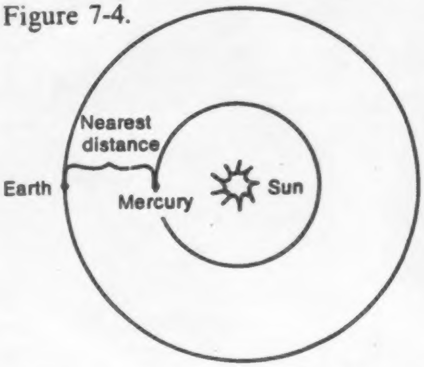
Figure 7-3



MEASURING THE SIZE OF MERCURY

Every few years the sun, the earth, and Mercury line up perfectly, with Mercury between the sun and the earth. This is shown in Figure 7-4.

Figure 7-4



When this happens, astronomers can photograph Mercury as it passes across the face of the sun. This is called a *transit.* Such a transit was observed in 1970, and there will be another in 1973, in 1986, and in 1993. Figure 7-5 shows Mercury crossing the sun.

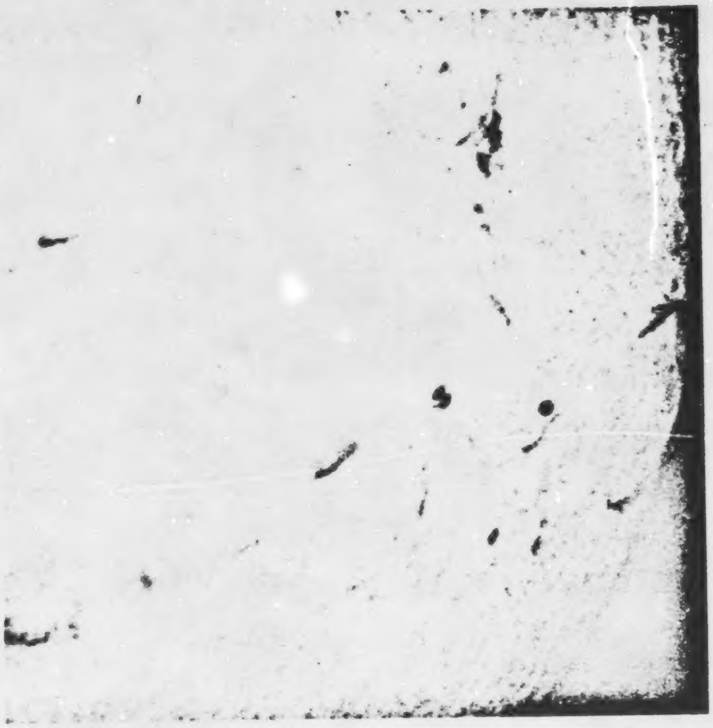


Figure 7-5

Perhaps you see how this information can be used to determine the diameter of Mercury.

Suppose, during a transit of Mercury, the apparent size of the planet was measured to be $\frac{1}{200}$ as wide as the sun that it was crossing. Find the diameter of Mercury, using the following data you have already worked out:

1. The distance to the sun—from Chapter 4
2. The size of the sun—from Chapter 5
3. The nearest distance from the earth to Mercury—your answer to question 7-5

☐**7-6.** Record the diameter of Mercury in your notebook.

For lack of time and better equipment, you have not used to the fullest the measuring techniques you've learned. By looking at spectra, astronomers can determine such things as the speed of moving objects, as well as their temperature and composition. Mathematics can be used to produce many, many other kinds of distance measurements.

Most people think of astronomers as constantly looking through big telescopes. Although the telescope is certainly important for gathering information about stars and planets, it is by no means the astronomer's only tool. In recent years, new ways of studying the heavens have been used. Not long ago, for example, it was discovered that some stars and groups of stars give off radio waves. By studying these waves, radio astronomers are locating objects that were unknown only a few years ago.

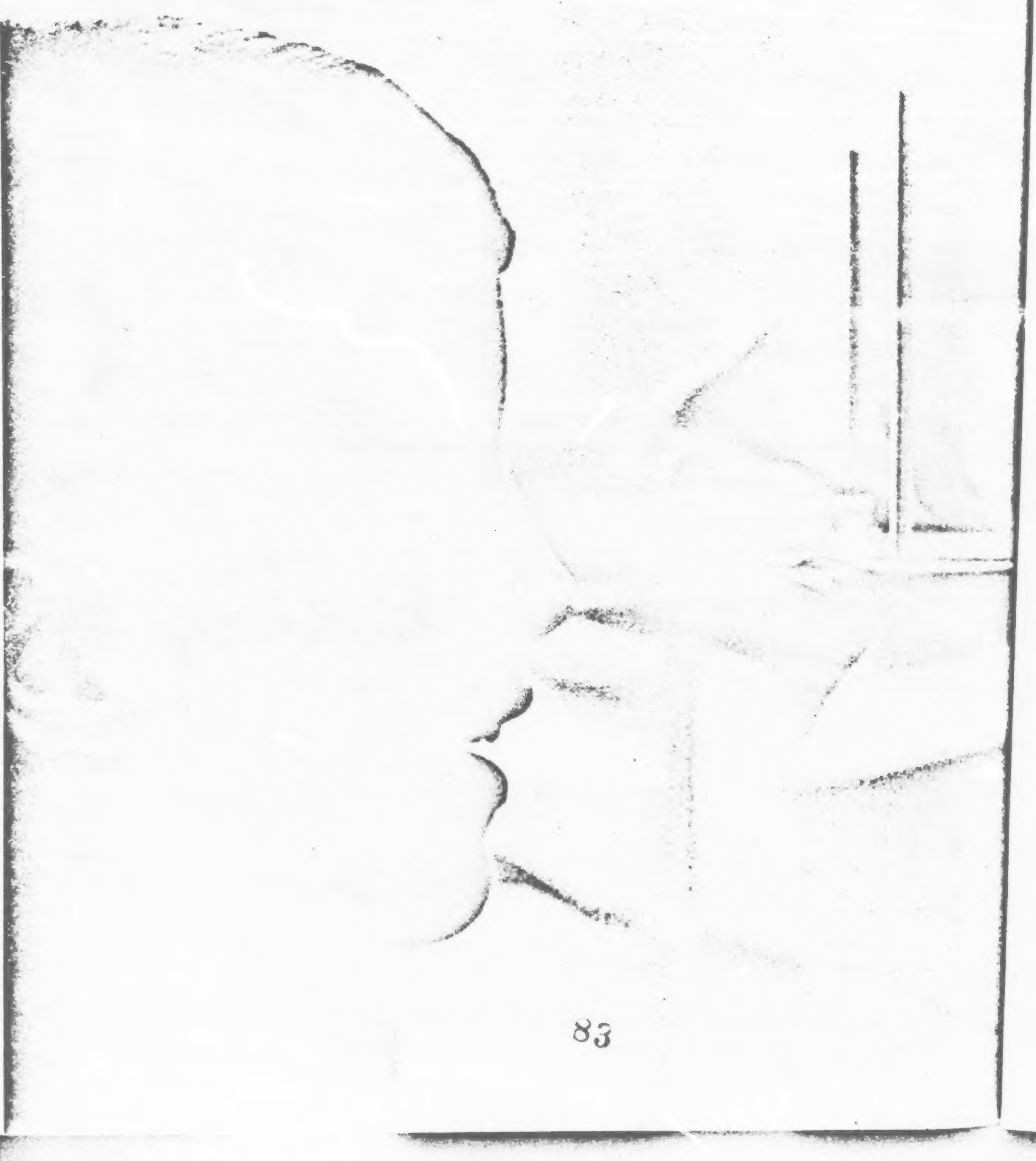
If you've done your work well, you now realize that a lot of work involves only a pencil, a piece of paper, and, most importantly, a lot of hard thinking. Of course, a computer comes in handy.

Before going on, do Self-Evaluation 7 in your Record Book.

Excursions

Do you like to take trips, to try something different, to see new things? Excursions can give you the chance. In many ways they resemble chapters. But chapters carry the main story line. Excursions are side trips. They may help you to go further, they may help you go into different material, or they may just be of interest to you. And some excursions are provided to help you understand difficult ideas.

Whatever way you get there, after you finish an excursion, you should return to your place in the text material and continue with your work. These short trips can be interesting and different.

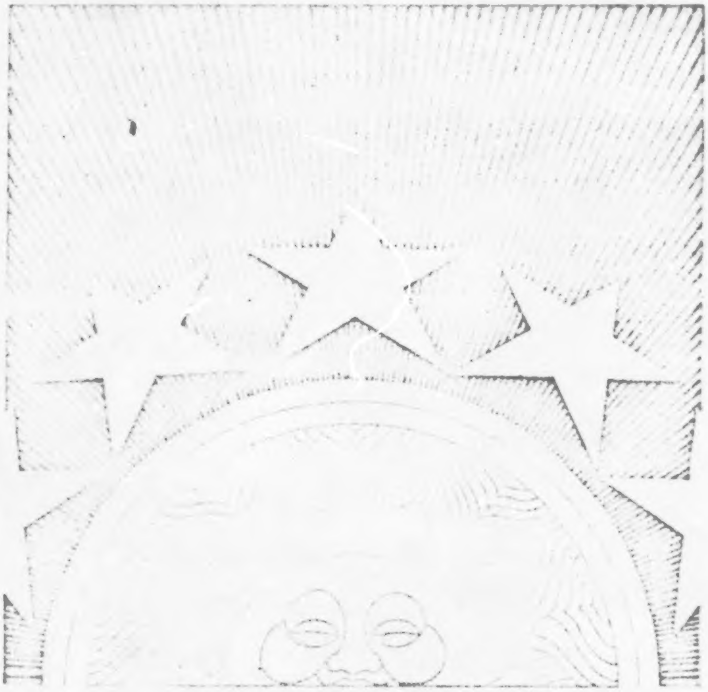


Those Strange Dark Lines

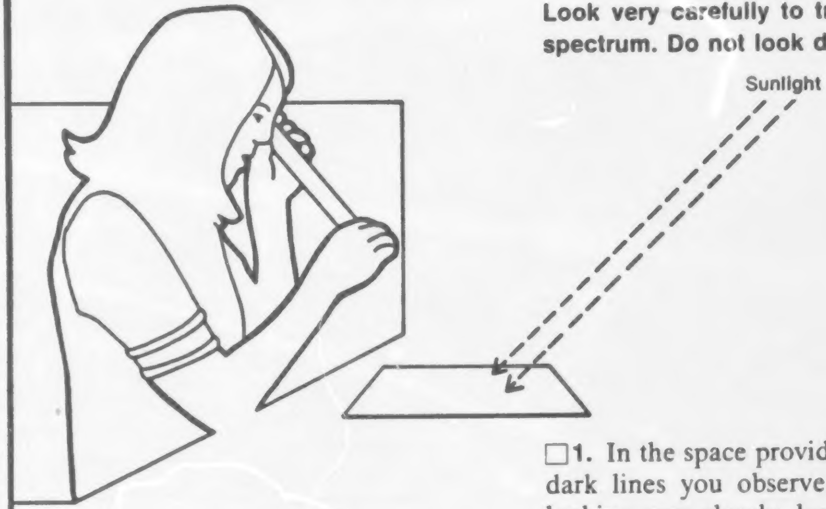
Excursion 1-1

Your work in Chapter 1 introduced you to bright-line spectra. Now perhaps you'd like to meet the black sheep of the spectral family. If so, start right in.

Safety Note: Remember not to look directly at the sun as you do the activities that follow.



ACTIVITY 1. Once again, use the spectroscope to study a bright spot of sunlight reflected from a piece of white paper. Look very carefully to try to locate a few dark lines in the spectrum. Do not look directly at the sun.



☐**1.** In the space provided in your Record Book, sketch any dark lines you observe. (If you don't see any lines after looking very closely, leave the space blank.)

Did you have difficulty seeing the dark lines in the spectrum of the sun? Don't feel too bad. Not only did some of the great scientists in the past not see the lines in the sun's spectrum, but some who did see the lines disregarded them. For example, one good scientist thought they were merely the boundaries between the various colors.

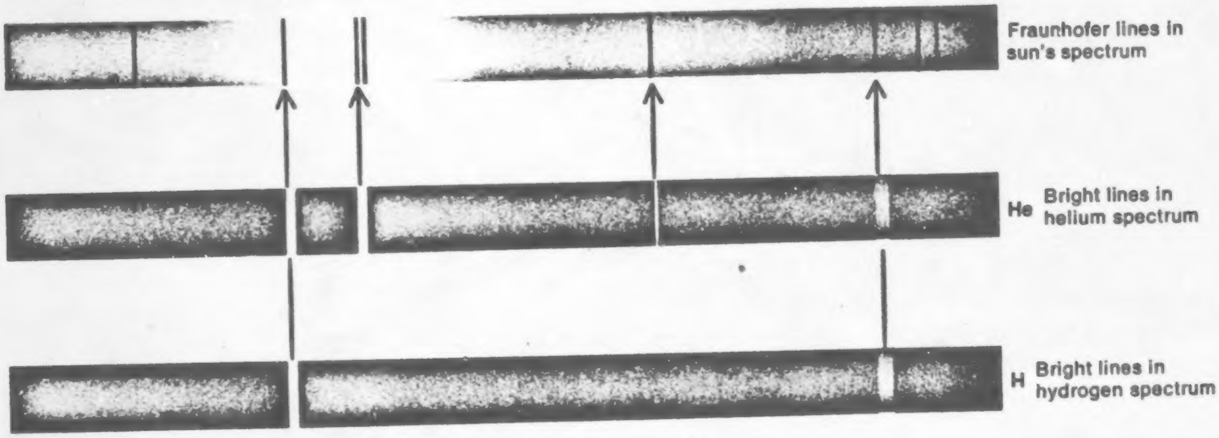
Joseph von Fraunhofer

The dark lines that cross the spectrum of the sun were first investigated by Fraunhofer in 1814. He measured but couldn't explain the positions of a great many of them. The lines are now called *Fraunhofer lines* in Fraunhofer's honor, but their explanation was the product of another great scientist, Kirchhoff.

It was found that these dark lines on the spectrum were in exactly the same position as the lines in the bright-line spectra of certain elements. The dark lines are believed to be caused when light from the sun's surface passes through the gases in the atmospheres of the sun and the earth. Figure 1 shows a comparison between the two kinds of lines.

The spectrum of the light from the sun has been photographed, and the positions of the dark lines noted. These lines have been compared with known spectral lines. In this way the astronomer has been able to predict what elements the atmosphere of the sun contains.

Figure 1


Fraunhofer lines in sun's spectrum
He
Bright lines in helium spectrum
H
Bright lines in hydrogen spectrum

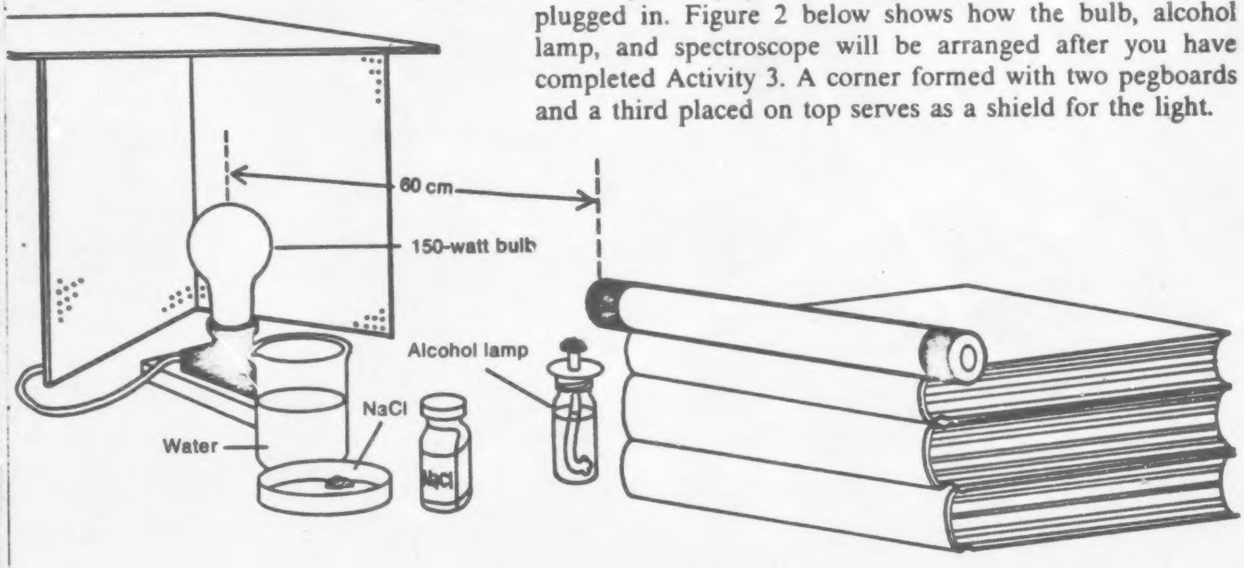
You can do a simple experiment that will let you see the Fraunhofer lines of the element sodium. You will need the following equipment:

3 pegboard backs
1 nichrome wire, 10 cm long
1 petri dish
1 alcohol burner
1 spectroscope
1 small container of water
1 150-watt bulb in parallel-circuit receptacle
1 small pinch of NaCl

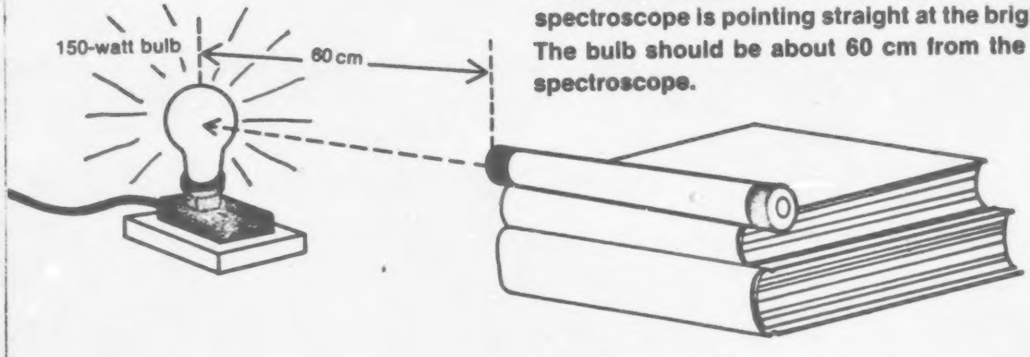
☐**2.** In the space provided, draw your predicted position of the dark lines of the Na spectrum. (Hint: What did you find for the bright-line spectrum?)

Take your equipment to a place where the bulb can be plugged in. Figure 2 below shows how the bulb, alcohol lamp, and spectroscope will be arranged after you have completed Activity 3. A corner formed with two pegboards and a third placed on top serves as a shield for the light.

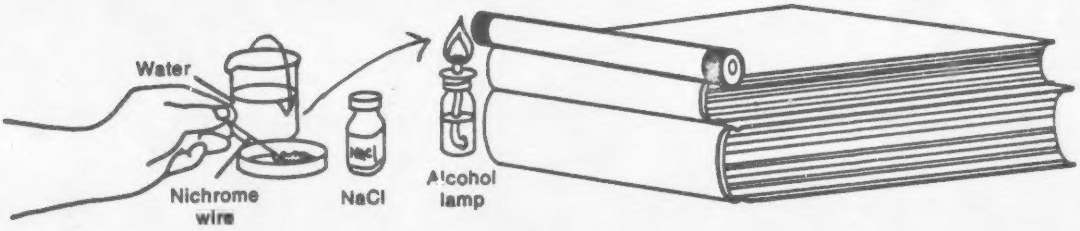
Figure 2



ACTIVITY 2. Plug in the 150-watt bulb. Support the spectroscope with books. Adjust the height of the books so that the spectroscope is pointing straight at the bright part of the bulb. The bulb should be about 60 cm from the closer end of the spectroscope.

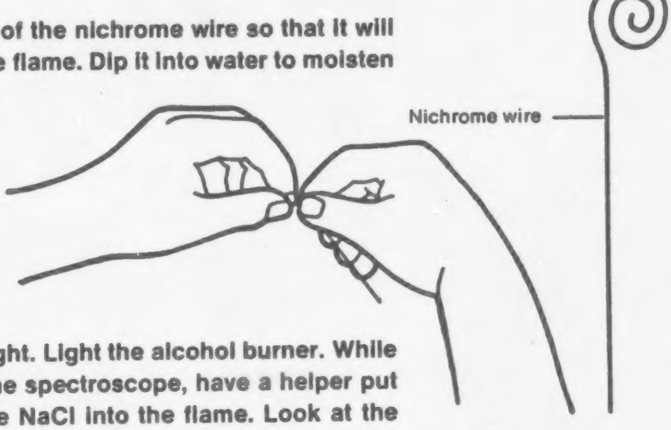


ACTIVITY 3. Turn off the 150-watt bulb. Place the alcohol burner close to the end of the spectroscope. Dip the nichrome wire into water and then into the NaCl. Then hold it in the flame, avoiding the wick. You should see the yellow sodium lines clearly through the scope. Adjust the height of the burner if necessary.

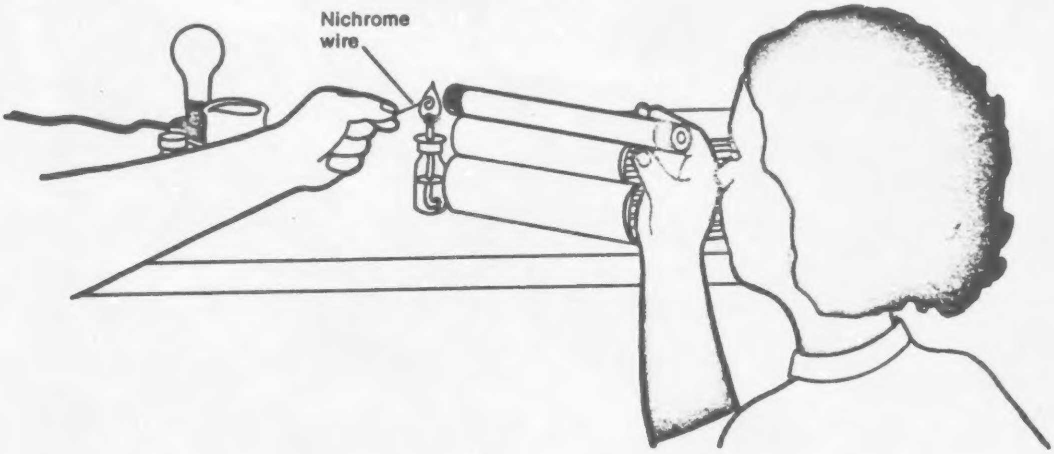


After you have completed Activity 3, you should be able to see the bright continuous spectrum from the bulb when it is turned on, and the bright yellow lines from the NaCl flame when the bulb is off, without having to move the spectroscope. Make the necessary adjustments until you can.

ACTIVITY 4. Twist the end of the nichrome wire so that it will hold more salt (NaCl) in the flame. Dip it into water to moisten it and then into the NaCl.



ACTIVITY 5. Turn on the light. Light the alcohol burner. While you are looking through the spectroscope, have a helper put the nichrome wire with the NaCl into the flame. Look at the spot where the bright yellow lines appeared before.



☐**3.** In the space provided in your Record Book, describe what you see.

If the observations are carefully made, and the lamp, flame, and spectroscope are lined up properly, the dark Fraunhofer lines should appear where the bright lines were before. The sodium (Na) vapor in the flame subtracts the yellow lines from the spectrum of the bulb. Fraunhofer noted that the measured positions of the dark lines were exactly the same as the bright lines of many of the elements in a flame.

☐**4.** How did your findings compare with your prediction in question 2?

Energy at Work

Excursion 2-1

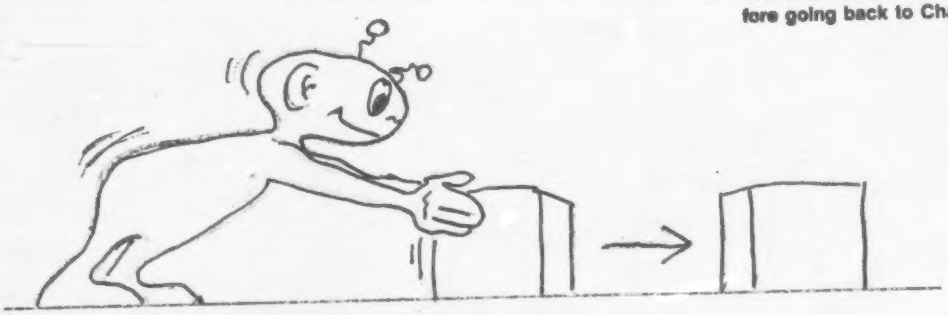
Answers to Checkup

The correct answers for the Checkup are 1 c; 2 b, d; 3 b, c, d; and 4 a, c. Notice that some questions had more than one correct answer. If you missed any of these, or if you checked any of the other choices, do this excursion before going back to Chapter 2.

Whenever possible, scientists use operational definitions in describing things they study. For example:

A scientific operational definition for work is

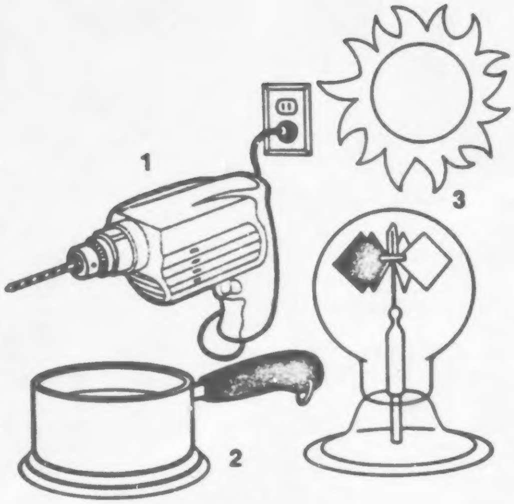
WORK = FORCE × DISTANCE



According to this definition, Iggy (above) is doing work if he does two things:

1. Applies a force to the box, and
2. moves the box some distance.

Somehow, Iggy has the ability to do work. This ability can be thought of as something present in him. We'll call it energy. The scientist, being precise, wants a more accurate definition of energy. He says, "Energy can do work."



The scientist's definition of energy has an interesting result. There are different kinds of things that can do work. Therefore, energy must exist in different forms.

For example, electrical devices (1) can do work; therefore, electricity is one form of energy.

Heat (2) also can be used in doing work. It, too, must be energy.

Light (3) is considered as another form of energy because it can do work.

Still other forms of energy exist. Chemical energy is an example.

You know from your own experiences that energy can be transferred from one place to another. Light, for example, travels to the earth from the sun. A hot object next to a cold one loses heat to the cold object. Electricity can move from a power plant to the lamp on your table.

☐**1.** Give another example of the transfer of energy.

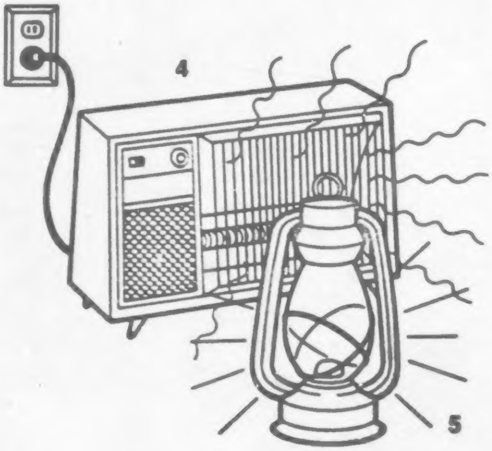
Remember, too, that energy can be changed from one form to another. For example:

Light can be changed to heat.
Electricity (4) can be changed to light and heat.
Heat (5) can be changed to light.

☐**2.** Can you give an example of heat being changed to electricity?

☐**3.** Can chemical energy be changed to electrical energy?

☐**4.** Give an example or two of how energy causes a change in matter.



When these changes in matter occur, and when one form of energy changes to another, no energy is lost or destroyed. Energy may be absorbed, released, changed in form, and spread around, but it is always somewhere—it is always conserved. Scientists refer to this fact as the conservation of energy.

Return now to Chapter 2.

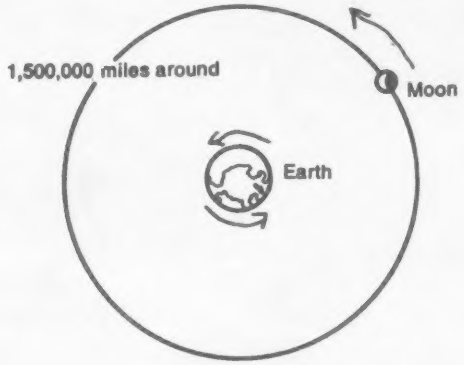
The Moon's Measurements

Excursion 3-1

During the 1968 Christmas holidays, the world was thrilled by the successful orbiting of the moon by three American astronauts. Of course, since then, several men have walked on the moon's surface. However, the first humans to get close to the moon's surface, astronauts Borman, Lovell, and Anders, were in an excellent position to measure the size of the moon.

Even though you are a long way from its surface, you too can measure the diameter of the moon. And you can do it almost as accurately as could the astronauts. All you need is a clock and the ability to visualize the motion of the moon with respect to the earth. Figure 1 will help you do this.

Figure 1



How do you calculate the distance around the moon's orbit? See the last part of this excursion.

Notice that the figure reminds you of two important assumptions. Keep these in mind as you proceed.

1. It is asumed that the moon's orbit is a circle, 1,500,000 miles around. The earth is placed at the center of that circle.
2. The earth turns at a constant speed.

As you may know, astronomers have shown that these assumptions are not completely accurate. They are close enough, however, to let you make the measurements you need.

On a night when the moon is full and the weather is clear, watch the moon for a few minutes. If you look carefully long enough, you will notice that the moon appears to move in the sky. If you know your directions, you may even notice that it moves from east to west. Look at Figure 2 and do some thinking.

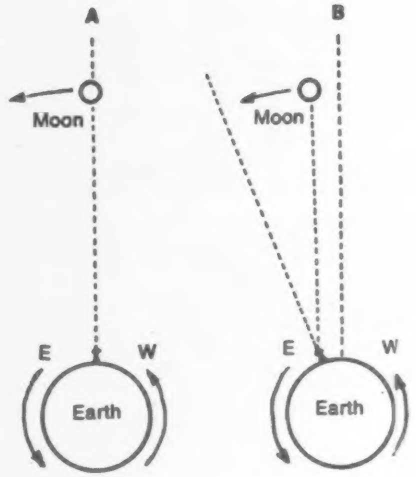


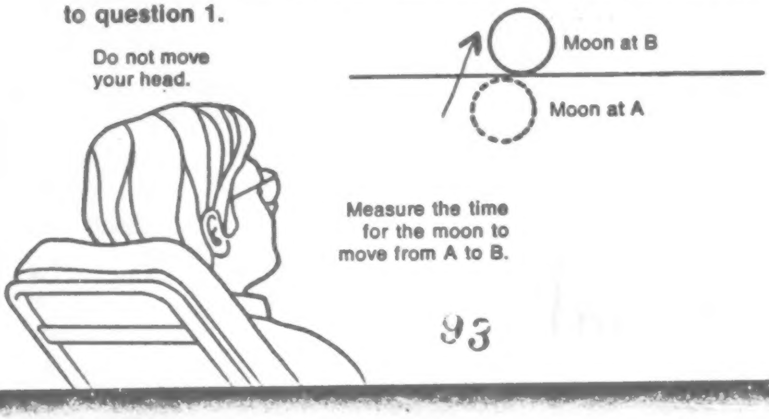
Figure 2

The apparent motion of the moon is influenced by two things: (A) the turning of the earth, and (B) the moon's movement in its orbit.

Astronomers have found that most of what appears to be the motion of the moon is due to the turning of the earth. In fact, it is reasonable to assume that when you view the moon for only short periods of an hour or so, all the motion observed is due entirely to the earth's turning. You will assume this to be so as you make the observation called for in Activity 1.

Your first problem will be to find out how fast the moon appears to move. Since doing this may take an hour or so, you'd better start your work fairly early in the evening.

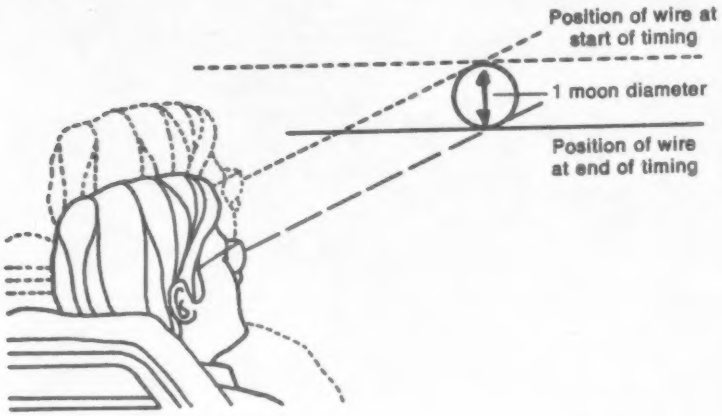
ACTIVITY 1. Line up the top of the moon with a power line or telephone wire. With your head resting against some object to keep your eye steady, time the movement of the moon across the wire. Record the time in minutes as your answer to question 1.


Do not move your head.
Moon at B
Moon at A
Measure the time for the moon to move from A to B.

☐**1.** How many minutes did it take the moon to pass across the wire?

Your answer to question 1 is a very interesting measurement. Figure 3 may help you figure out what it means. The drawing is based upon the assumption that the earth's motion makes the moon appear to move.

Figure 3


Position of wire at start of timing
1 moon diameter
Position of wire at end of timing

The rotation of the earth moves the wire and observer to a new position with respect to the moon. Since the observer thinks he is motionless, he naturally believes the moon has moved.

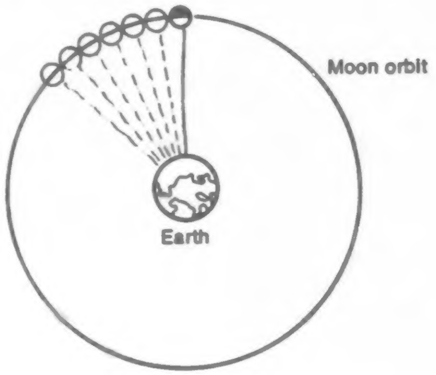
☐**2.** In question 1, you recorded the minutes it takes for the wire to sweep across one moon diameter. How many minutes did this sweep take?

☐**3.** How many minutes does it take the earth to make one complete rotation?

☐**4.** How many moon diameters would a telephone wire sweep across in one full day? (Hint: You know the time needed to sweep across one moon diameter. You also know how many minutes there are in one full day.)

You now have enough information to calculate the moon's diameter. Your answer to question 4 tells you how many moon diameters there are in one moon orbit. Figure 4 illustrates this.

Figure 4



You also know the length in miles of the moon's orbit (1,500,000). The following relationship allows you to make the final calculation.

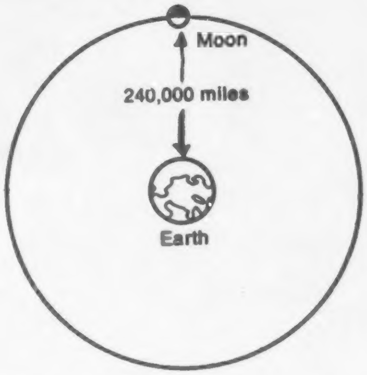
$$\text{Diameter of moon (in miles)} = \frac{\text{Length of moon's orbit (in miles)}}{\text{Number of moon diameters in one orbit}}$$

☐ **5.** What is the diameter of the moon?

Special note to students on calculating the length of the moon's orbit

Are you wondering how the moon's orbit was measured? In Chapter 3 you learned that the moon is about 240,000 miles from the earth (Figure 5).

Figure 5



You may know that the distance around any circle (circumference) may be found by multiplying the distance across the circle through its center (diameter) by a constant called π (pronounced "pie"). The value of π is approximately $\frac{22}{7}$, or 3.14. With this in mind:

Distance around = π × distance across
= π × 2 × half the distance across
= 3.14 × 2 × half the distance across
= 6.28 × half the distance across

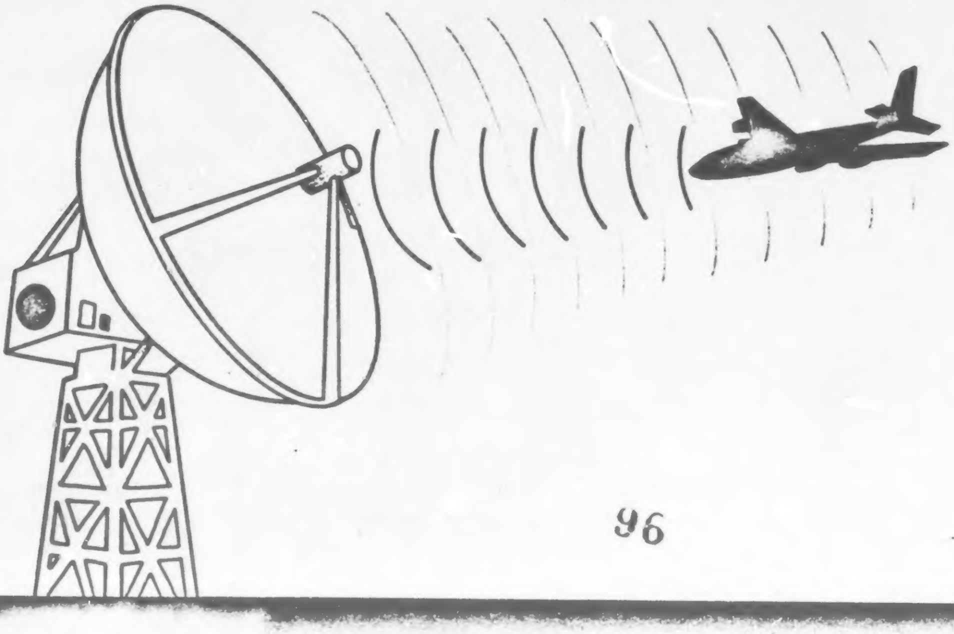
In Figure 5, "half the distance across" the circle is the distance from the earth to the moon. Thus we write:

Length of the moon's orbit
= 6.28 × distance from the earth to the moon
= 6.28 × 240,000 miles
= 1,500,000 miles

What's Radar? Excursion 4-1

What is radar? The name *radar* was coined from the words *RA*dio *D*etection *A*nd *R*anging by two United States naval officers, F. R. Furth and S. M. Tucker. Radar is the process of using radio pulses to detect the location of an object. In the process, very short powerful pulses of radio energy are transmitted. They bounce off the object and return to the sending station a bit weaker.

Radar technicians measure how long it takes for a pulse to travel to an object and back. The longer it takes the pulse to return from an object, the farther away the object must be. Thus, by measuring time of travel of the pulse, it is possible to determine the distance a target is from the radar set.



This is precisely how radar was used to measure the distance to Venus. Radio pulses travel at 186,000 miles/sec. A pulse of energy was beamed at Venus. Then the radar operator waited until his antenna received the reflected signal. Since the round-trip time was about 280 seconds, the one-way trip took half this time; that is, the pulse required 140 seconds, or 2⅓ minutes, to travel from Earth to Venus (Figure 1).

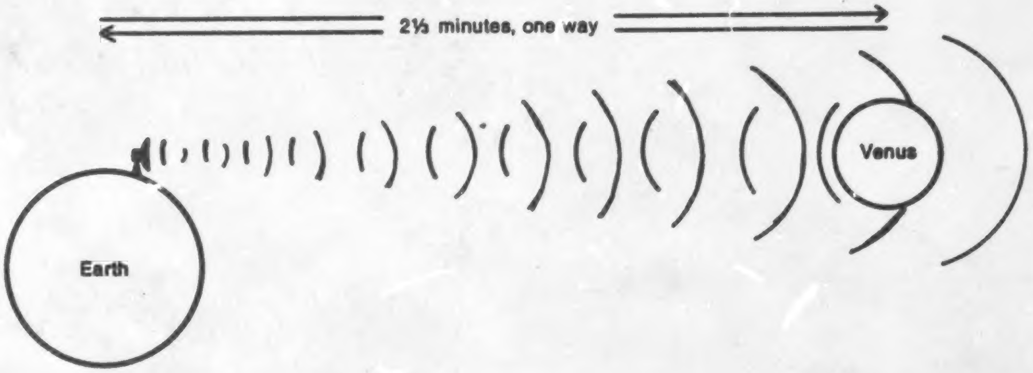


Figure 1

You probably know how to use speed and time measurements to find the distance traveled.

☐**1.** How far will a radio pulse travel in 1 minute if it moves 186,000 miles/sec?

☐**2.** If the pulse takes 2.33 minutes to travel from Venus to Earth, how far has the pulse traveled?

☐**3.** How far is Venus from Earth?

SOFT
TARGET

Using the methods discussed above, radar locates airplanes and ships, birds and thunderstorms, man-made satellites and planets. The same principle has also been used to measure the distance to Mars, Mercury, and of course to our moon.

So far, scientists have not been able to use radar to accurately measure the distance to the sun. Being a body composed mainly of hot gases, the sun is what scientists call a "soft" target rather than a hard target such as a planet. Therefore, although radar can give the distance to Venus to use as a base line in measuring the distance to the sun, it cannot accurately give the distance to the sun.

Angles and Protractors Excursion 4-2

As you open a pair of scissors, the angle (opening) formed by the blades changes.

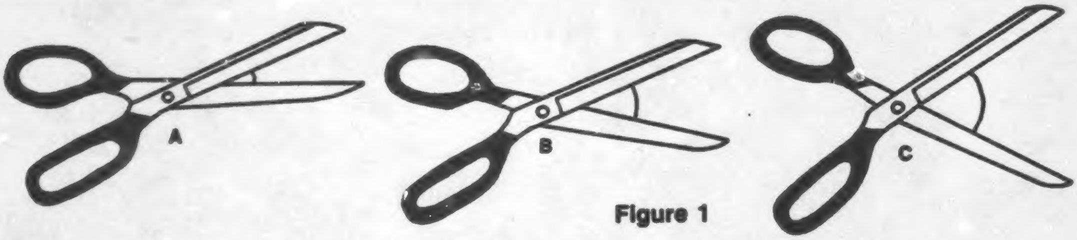


Figure 1

☐**1.** Which angle formed by the blades in Figure 1 is the largest?

Whenever two lines meet, an angle is formed. The meeting point of the lines is the *vertex* of the angle (Figure 2).

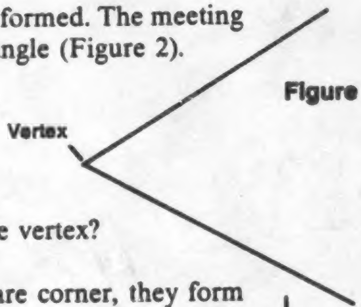


Figure 2

☐**2.** Can an angle have more than one vertex?

When two lines meet to form a square corner, they form a *right angle* (see Figure 3).

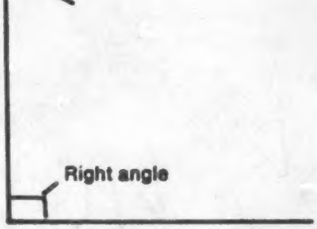


Figure 3

☐**3.** List some examples of right angles formed by objects in your classroom.

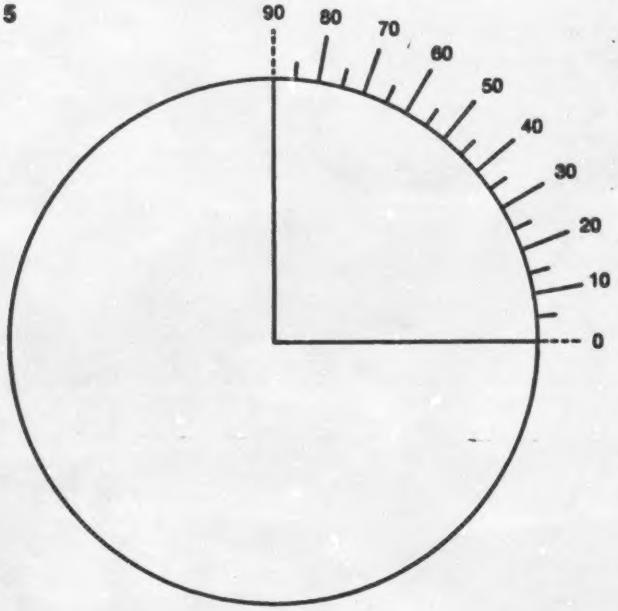
Notice the curved lines used to indicate angles in Figure 4. Such a line can indicate any angle you are interested in. Right angles are usually represented by a square, as in Figure 3.

Figure 4

Circles are measured by dividing them into equal parts called degrees. These are not the same kind of degrees you remember from your earlier work with temperature. However, the same symbol is used for angle degrees.

Thus a right angle contains 90° (Figure 5).

Figure 5



☐**4.** What portion of a circle is a right angle (90°)?

☐**5.** If a right angle contains 90°, how many degrees are in a complete circle?

Look at your protractor. It should be positioned with its center point on the vertex B of angle ABC, and its zero point on line BC. This is shown in Figures 6A and 6B.

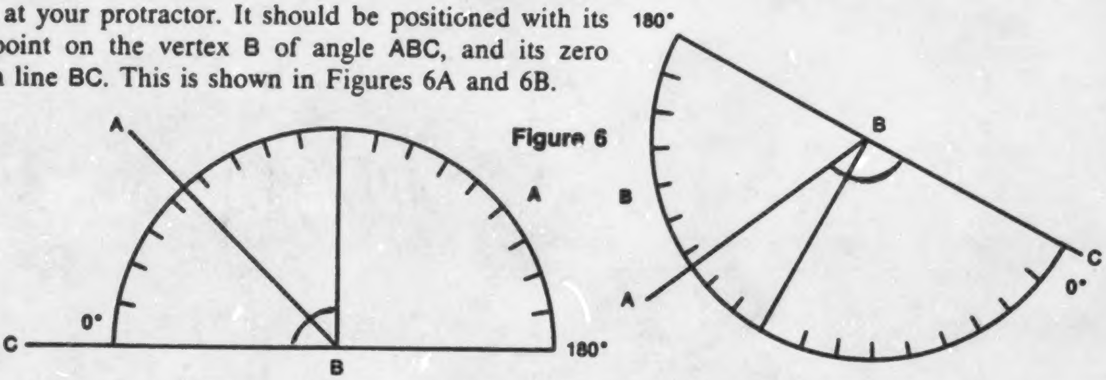
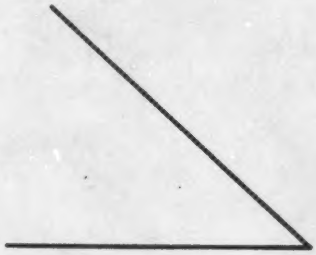


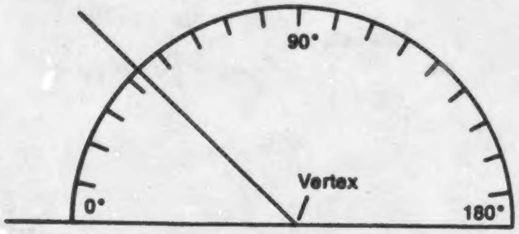
Figure 6

Some protractors have two scales. You then use whichever one is easier in reading the desired angle. In the following illustrations, a protractor with only one scale is shown. Figure 7 provides an angle for you to measure for practice. Activities 1 and 2 show you how to do it if you need additional help.

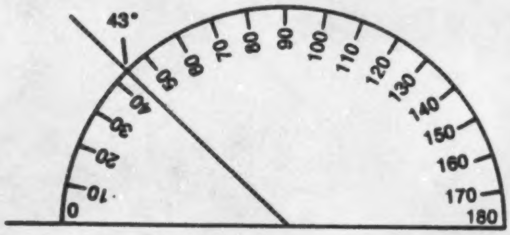
Figure 7



ACTIVITY 1. Set the protractor on the angle with the center point on the vertex and the curved part of the protractor covering the angle. The 0° mark must touch one side of the angle. Notice that the protractor forms a curved line like the ones you've seen in the drawings so far.



ACTIVITY 2. Read the number on the scale that the other side of the angle passes through.



Measure the angles in Figure 8 to the nearest whole degree. Record your measurements in Table 1. Have your teacher check your figures to be sure that you understand how to use the protractor.

Figure 8

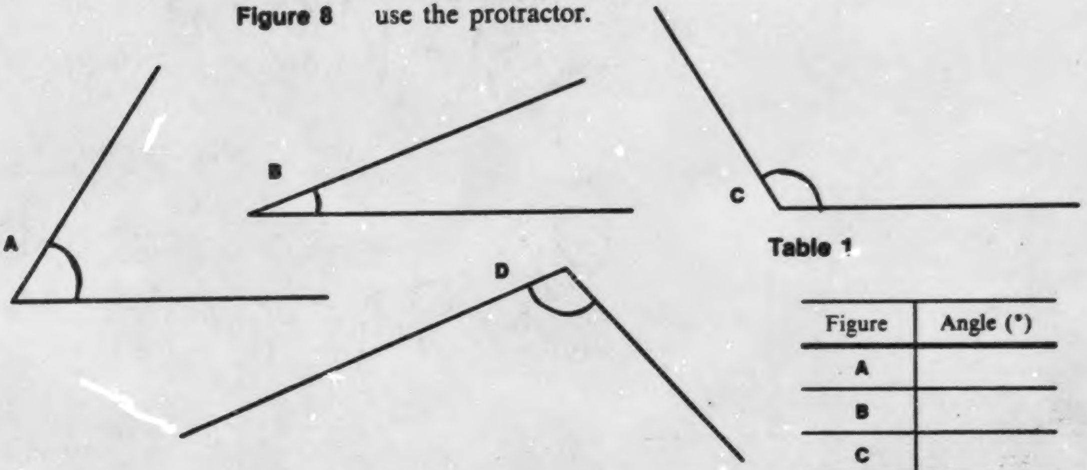
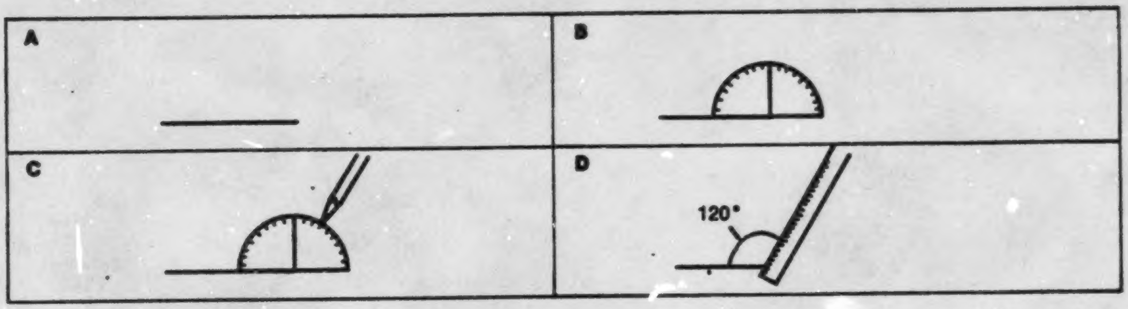


Table 1

Figure	Angle (°)
A	
B	
C	
D	

Now that you have measured some angles, try to draw some angles of certain sizes. Activity 3 shows you how.

ACTIVITY 3. A. Draw a line. B. Place protractor with center on one end of the line. C. Mark a point by the desired angle. D. Connect this point with the line's endpoint.



☐**6.** In the space provided in your Record Book, draw the following angles: 72°, 30°, 115°.

Have your teacher check your drawings. When he approves, you are ready to return to your work in Chapter 4.

Scale Drawings

Excursion 4-3

If you know the scale used in a drawing, you can determine the actual size of the object drawn. Look at Figure 1. It is a simple plan for a new building.

☐**1.** What scale did the architect use?

☐**2.** How many centimeters wide is the storage area as shown in the drawing?

☐**3.** When the warehouse is actually built, how wide will the storage area be?

Answers to Checkup

1. 16 feet (Consider 15 or 17 to be close enough.)
2. 14 feet (Consider 13 or 15 to be close enough.)

If you missed either of these questions, do this excursion before returning to Chapter 4.

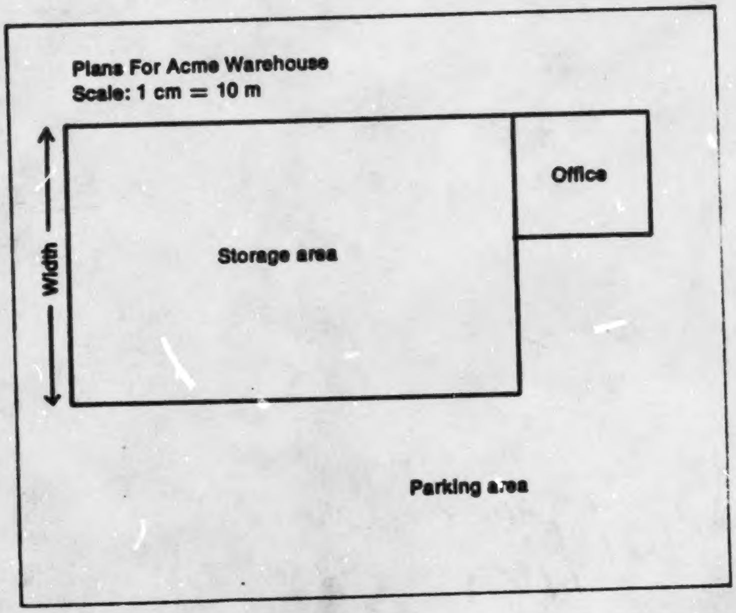
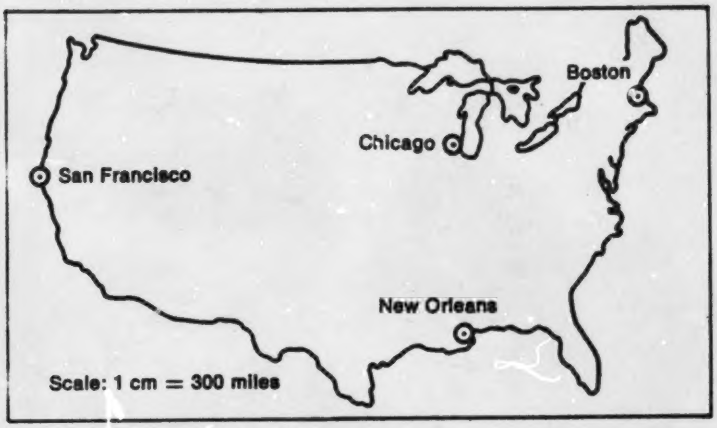

Plans For Acme Warehouse
Scale: 1 cm = 10 m
Office
Width
Storage area
Parking area

Figure 1

Your answer to question 2 should be 4 cm. The answer to 3 should be 40 m. (This results from multiplying 4 × 10. Remember that 1 cm on the drawing represents 10 m in the finished building.)

☐4. Use the information in Figure 2 to answer these questions:

Figure 2



What is the actual distance
- A. from Boston to Chicago?
- B. from Chicago to San Francisco?
- C. from Chicago to New Orleans?

If your answers to question 4 were A. 840 miles, B. 1,800 miles, and C. 840 miles, you are ready to continue with Chapter 4. If you missed any of the parts to question 4, consult with your teacher before going ahead.

Practice in Using Scale Drawings

Excursion 4-4

How can you find the distances from Earth to the sun and Venus to the sun by using a scale drawing? The sketch in Figure 1 is a scale drawing. Measure the distances shown on the drawing: VS, ES, and EV. Try it.

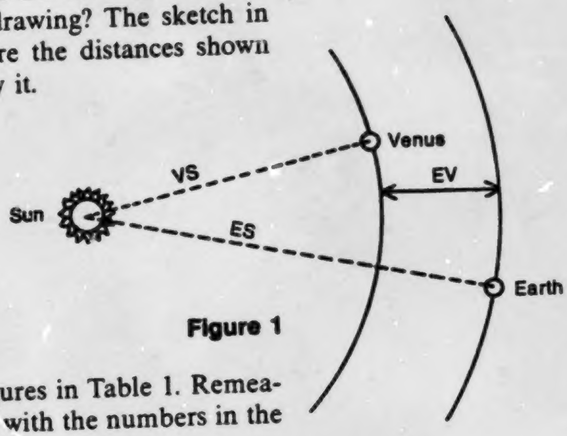


Figure 1

Compare your results with the figures in Table 1. Remeasure any distances that do not agree with the numbers in the table.

Table 1

	Scale Drawing (Distance in mm)	Actual Distance (in miles)
Venus to Sun (**VS**)	43	?
Earth to Sun (**ES**)	60	?
Earth to Venus (**EV**)	17	26,000,000

☐**1.** From Table 1 you see that 17 mm on the drawing represent 26,000,000 actual miles. How many actual miles would be represented by 1 mm? Of course, $\frac{1}{17}$ as many miles, or 1 mm on the drawing, represents $\frac{1}{17} \times 26{,}000{,}000$ actual miles = how many miles?

☐**2.** How many actual miles would be represented by 2 mm on the drawing?

☐**3.** Now figure out the Venus–sun distance for Table 1. How many actual miles are represented by 43 mm? 43 mm in the drawing represent $\frac{43}{17} \times 26{,}000{,}000$ actual miles = how many miles?

☐**4.** Using the same method, you can find the Earth–sun distance. The Earth–sun distance on your drawing is 60 mm. How many actual miles are represented by 60 mm?

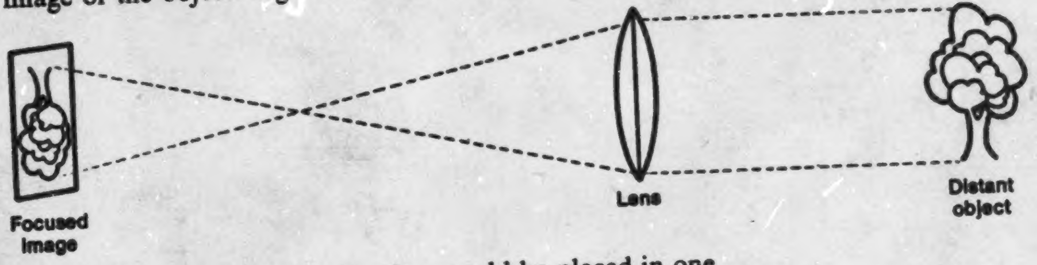
You should have gotten about 66,000,000 actual miles as an answer for question 3. About 92,000,000 actual miles should be your answer for 4. Record these results in Table 1 in your Record Book. Now return to Chapter 4 and complete Table 4-2. If you continue to have difficulty, consult your teacher.

Moon Gazing

Excursion 5-1

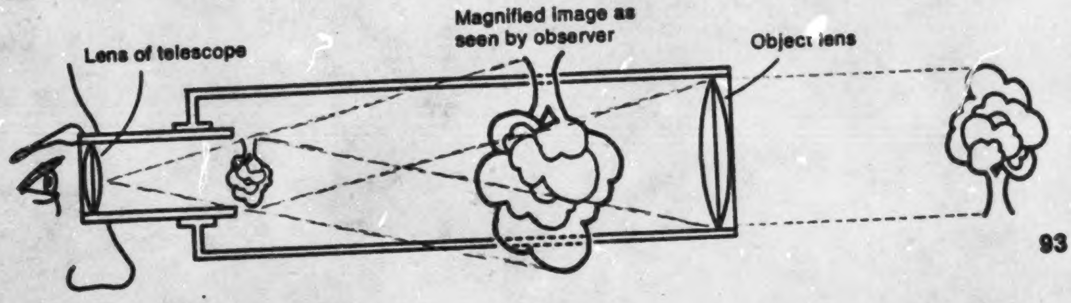
A Dutch eyeglass maker, Hans Lippershey, discovered the principle of the telescope. He found that an eyeglass lens can focus light coming from a distant object. As light passes through the lens, the light rays are brought closer together. They eventually cross and can form an image on a flat surface. The crossing of the light rays produces an upside-down image of the object. Figure 1 illustrates this.

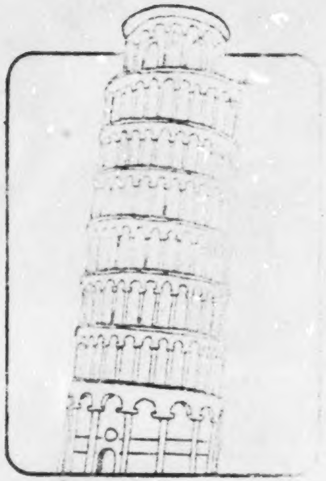
Figure 1


Focused image
Lens
Distant object

Lippershey found that such a lens could be placed in one end of a cylinder. A smaller lens, placed at the other end, could be used to magnify the image. (See Figure 2.)

Figure 2


Lens of telescope
Magnified image as seen by observer
Object lens



Lippershey probably didn't think of using his telescope to look at the stars or moon. But others who heard of the new gadget did. Soon instruments were being made just for that purpose. One person who made his own telescope and used it for sky gazing was the scientist Galileo. Perhaps you've heard of him. He's the same fellow who tested the idea that objects with different masses fall at the same rate.

People who use telescopes don't just want to see distant objects. They want to see as much detail as possible. To understand how this is achieved, you need to know a bit more about the lenses in the telescope.

The distance from the object lens to its focus is called the *focal length of the object lens.* Likewise, the distance from the eyepiece lens to its focus is the *focal length of the eyepiece.*

The power or magnification of a telescope is calculated by using the following equation.

$$\text{Power} = \frac{\text{Focal length of object lens}}{\text{Focal length of eyepiece}}.$$

☐**1.** Suppose a telescope has an object lens with 30-cm focal length and an eyepiece lens with 5-cm focal length. Determine the power of the telescope.

The greater the focal length of the object lens as compared with the focal length of the eyepiece, the greater the magnification. However, when you magnify size, you also magnify motion. So the greater power the telescope has, the steadier you must hold it. Even the slightest motion may make the image seem to float, bobbing up and down and sideways like a cork on a windswept pond.

☐**2.** Why must giant telescopes at observatories rest on massive concrete foundations?

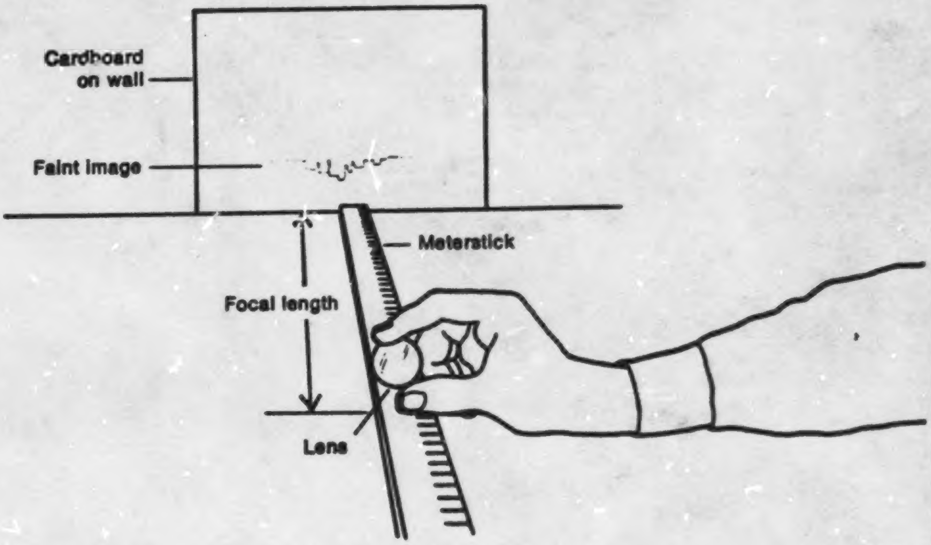
Perhaps you'd like to construct an instrument similar to the one Galileo made, and use it as he did—to observe the surface of the moon, its craters, flat plains (called seas), and mountains. If so, you will need the following equipment:

1 cardboard tube, 40 cm long, with inside tube and end caps
1 object lens, 34 mm in diameter
1 eyepiece lens, 25 mm in diameter

1 cardboard, 15 cm square, with white surface
Meterstick
Masking tape

In order to know the power that your telescope will have, you need to find the focal lengths of the two lenses. Be careful in handling them. Do not drop them, as they break easily. When you are ready to start, go to the darkest part of the room and prop the cardboard flat against the wall.

ACTIVITY 1. Hold the object lens (the larger lens) by the edge, in front of the cardboard. Move the lens toward or away from the cardboard until a faint image of a distant object appears on the cardboard. The distance from the lens to the cardboard will then be its focal length. Use the meterstick to measure this distance.



☐**3.** What is the focal length, in cm of the object lens?

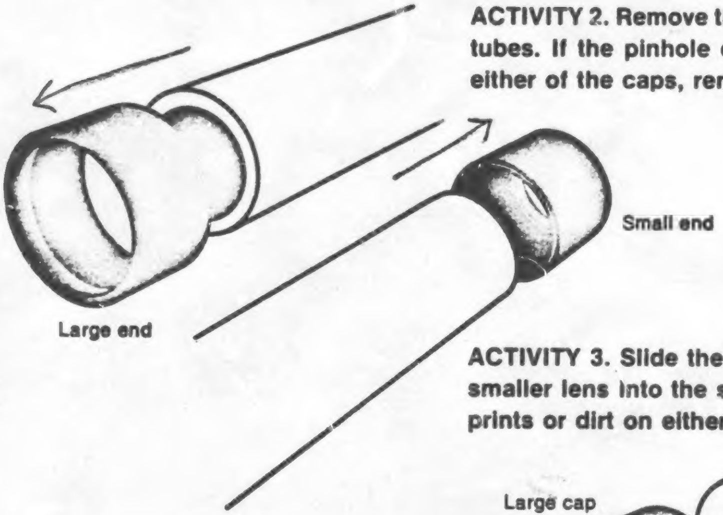
Repeat Activity 1 with the eyepiece lens. This time the focal length should be much shorter.

☐**4.** What is the focal length of the eyepiece lens, in cm?

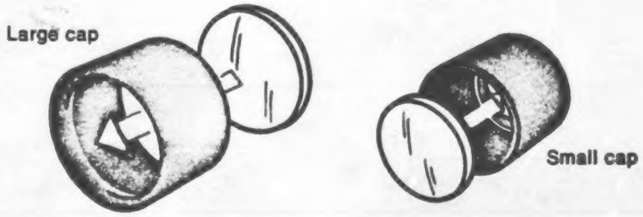
☐**5.** Using the equation given earlier, calculate the power of your telescope.

Now continue with the telescope construction.

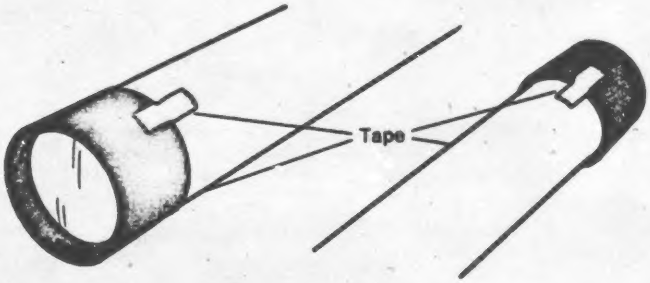
ACTIVITY 2. Remove the two caps from the ends of the sliding tubes. If the pinhole disk or the acetate grid disk is still in either of the caps, remove it and return it to your teacher.



ACTIVITY 3. Slide the larger lens into the large cap and the smaller lens into the small cap. Be careful not to get fingerprints or dirt on either lens.



ACTIVITY 4. Replace the caps on the tubes. Secure them with small pieces of tape.



Take your telescope to the window. Rest it on the ledge or against the window and point it toward a distant object other than the sun. Hold the eyepiece close to your eye. Slide the outer tube out or in until you can see a sharp image.

Safety Note *Remember, do not look at the sun.*

☐6. Describe anything different about the image that you observe (different from what you would see with the naked eye).

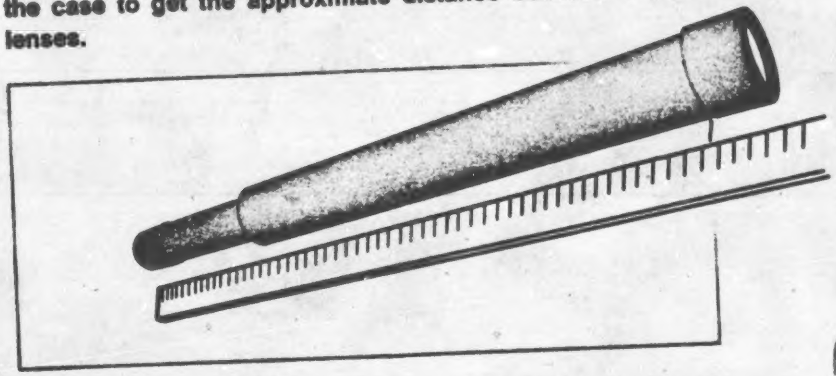
Besides magnifying, your telescope did something else that was unusual. You should have described it above. This is a common trait of astronomical telescopes. However, it is not bothersome.

☐7. Why is the unusual trait not bothersome to astronomers?

Your telescope will give maximum magnification when the distance between the lenses is about equal to the sum of their focal lengths.

☐8. How far apart should the lenses be in your telescope to give it the maximum magnification?

ACTIVITY 5. Sight a far object to adjust your telescope for maximum magnification. Then measure along the outside of the case to get the approximate distance between the two lenses.



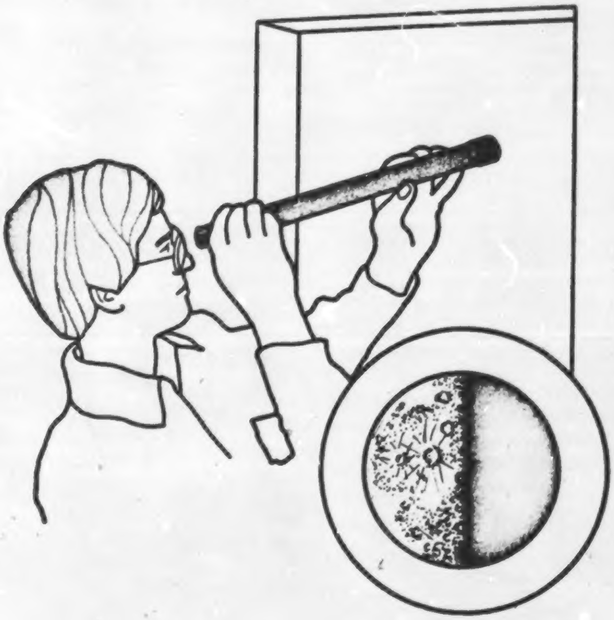
Any difference between what you measured in Activity 5 and what you predicted in question 8 will be due in part to individual eye differences (assuming that you answered question 8 correctly).

Incidentally, if you were to buy a telescope, field glasses, or binoculars, you might see two numbers listed in the descriptive literature. You might, for example, see "8 × 30" (read "eight by thirty"). The first number is the power—in this case, a magnification of 8 times. The second number

gives the diameter of the object lens in millimeters—in this case 30 mm. The latter figure is important. It tells you the light-gathering ability of the instrument. The higher this number is, the more light it allows to enter the instrument. Instruments with greater light-gathering ability work better at night.

☐**9.** Give the descriptive numbers for the power and light-gathering ability of your telescope.

Now that you have made a telescope, ask your teacher if you may use it at night to observe the moon. You should be able to identify some of the moon's features.

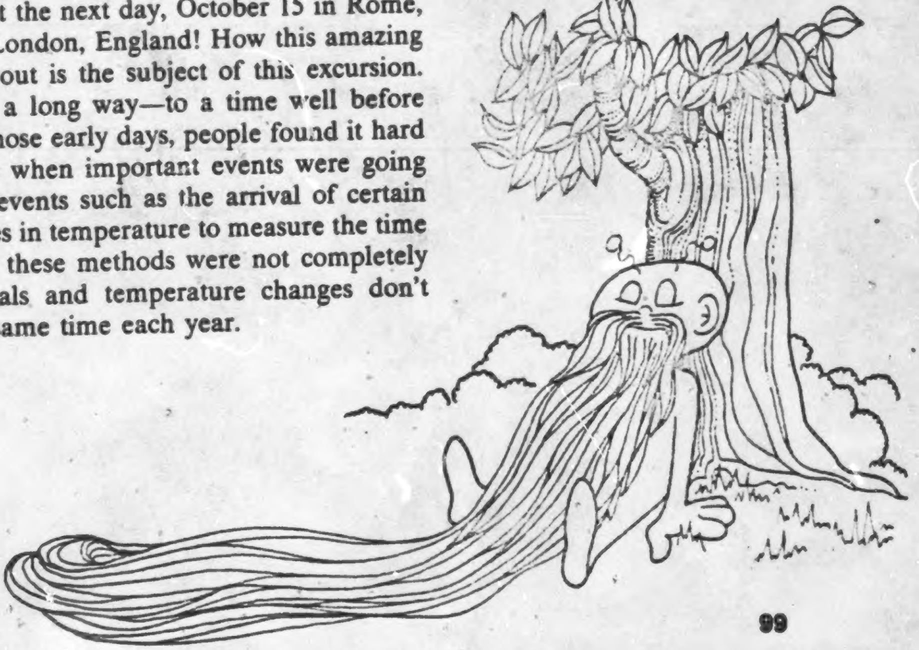


The Night That People Lost 10 Days

Excursion 6-1

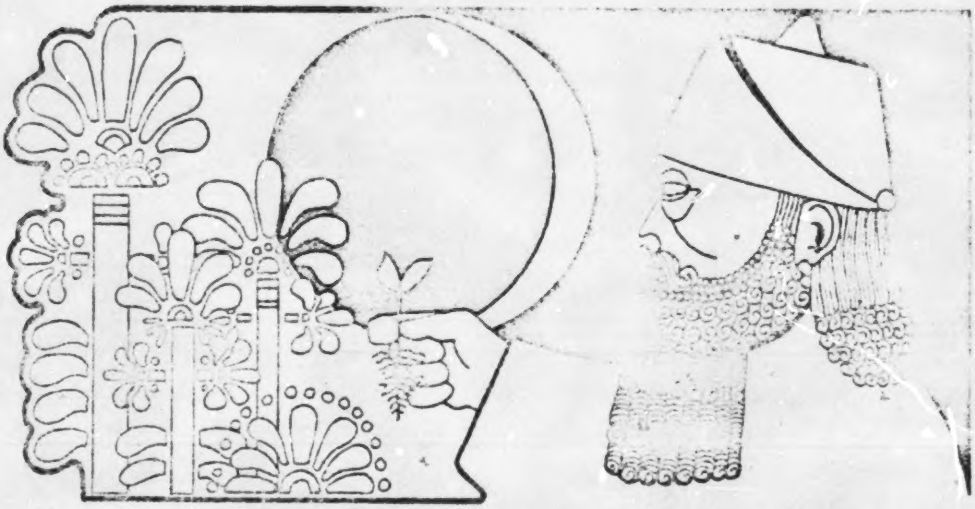
You've probably heard the story of Rip Van Winkle, who slept for 20 years, but have you heard about the night the people of Rome, Italy, actually slept away 10 days? It seems incredible, but in 1582 everybody in Rome went to bed on October 4 and woke up on October 15. Even more remarkable is the fact that the next day, October 15 in Rome, was only October 5 in London, England! How this amazing turn of events came about is the subject of this excursion.

The story goes back a long way—to a time well before the birth of Christ. In those early days, people found it hard to predict and describe when important events were going to happen. They used events such as the arrival of certain kinds of birds or changes in temperature to measure the time of the year. Of course, these methods were not completely satisfactory. Bird arrivals and temperature changes don't happen at exactly the same time each year.



To solve the problem of knowing the time of the year, people had to develop a calendar—a system of timekeeping based on some regularly occurring event. They found that at least three such events could be used.

1. The time from one full moon to the next
2. The time from one sunrise to the next
3. The time from one spring to the next (Astronomers determined the first day of spring by observing the exact time the sun passed a particular point in the sky on its north-south journey.)



EARLY CALENDARS

The Sumerians lived more than 4,000 years ago in what is now Iraq. They were probably the first people to make a calendar. They used the phases of the moon to determine how long a month was (about 30 days). In the Sumerian calendar, twelve lunar months (360 days) made a year.

☐**1.** How many days shorter than our year was the Sumerian year?

The Sumerians tried to make up the difference between their year and the amount of time that passed between springs by adding an extra month about every fourth year.

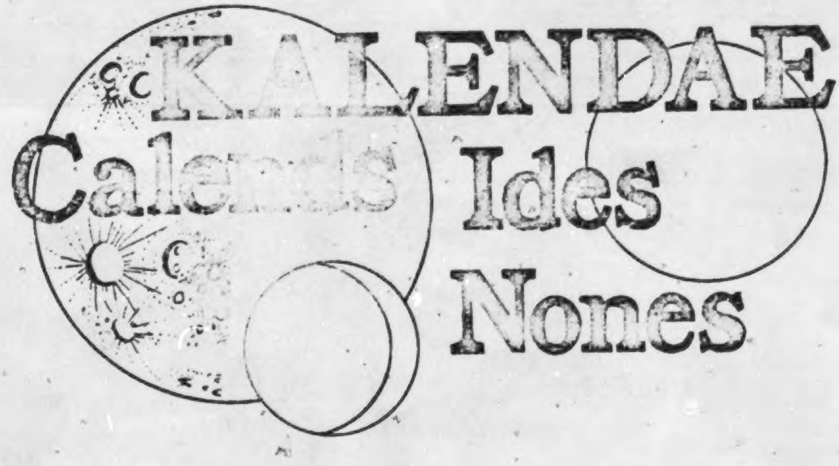
☐**2.** About how often should the Sumerians have added a 30-day month to get a year as big as ours?

As you can probably see, there were problems with this calendar. The Sumerians were never able to adjust their calendar so that the seasons arrived in exactly the same month each year. Although the Greeks, the Hebrews, and the Egyptians made improvements in the Sumerian calendar, the problem continued.

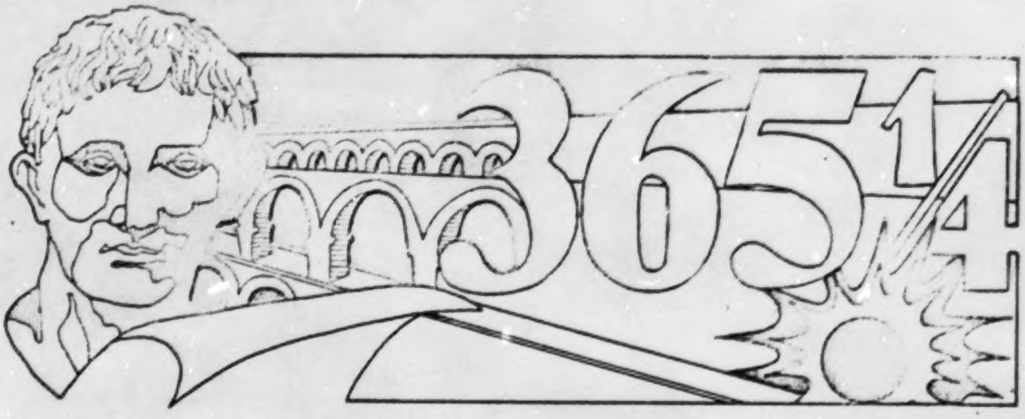
The calendar of the early Romans was also based on the phases of the moon. The Roman year was 355 days long. The months that corresponded to our March, May, July, and October were 31 days long. February had 28 days, and each of the other seven months had 29 days. The Romans, like the Sumerians, added an extra month every fourth year.

The word *calendar* comes from the Latin word *kalendae*—the first of the Roman month. This was the day that accounts were entered in an account book (*kalendarium*) and paid. You can see that the custom of paying bills on the first of the month goes back a long way.

The Roman high priest kept track of the calendar. On each calends, or day of the new moon, the priest announced the phases of the moon for that month. The first quarter phase was called the nones. The full moon was the ides.



☐**3.** You may have heard the famous quote from Shakespeare's *Julius Caesar*: "Beware the ides of March." What is meant by the ides of March?



JULIUS CAESAR'S CALENDAR

By 46 B.C., the Roman Emperor Julius Caesar had become quite unhappy with the Roman calendar. Because the high priests had done a poor job of keeping track of the calendar, the summer months were now coming in the spring. To solve the problem, Caesar introduced what became known as the Julian calendar.

The Julian calendar was devised by the Egyptian astronomer Sosigenes. It had a 365-day year (10 days longer than the Roman calendar). The extra 10 days were added to the months with 29 days, making them identical with the months on today's calendar.

The unique feature of the Julian calendar was the extra day added to every fourth (or leap) year. This produced the same result that adding a quarter of a day to each year would produce. In effect, this meant that the Julian year was $365\frac{1}{4}$ days long. This is almost, but not exactly, as long as the earth takes to make a complete turn around the sun. Because the Julian year was only a few minutes per year longer than the earth year, the change of seasons occurred on almost the same date every year.

We would probably be using the Julian calendar today if it were not for something that happened A.D. 325. That year there was an important meeting of church officials in Nicaea (in what is now Turkey). At the Council of Nicaea, the bishops decided that Easter would be celebrated on the first Sunday after the first full moon that occurs on or after the first day of spring. A.D. 325 the first day of spring occurred on March 21; this meant that Easter could not occur before March 22 or after April 25.

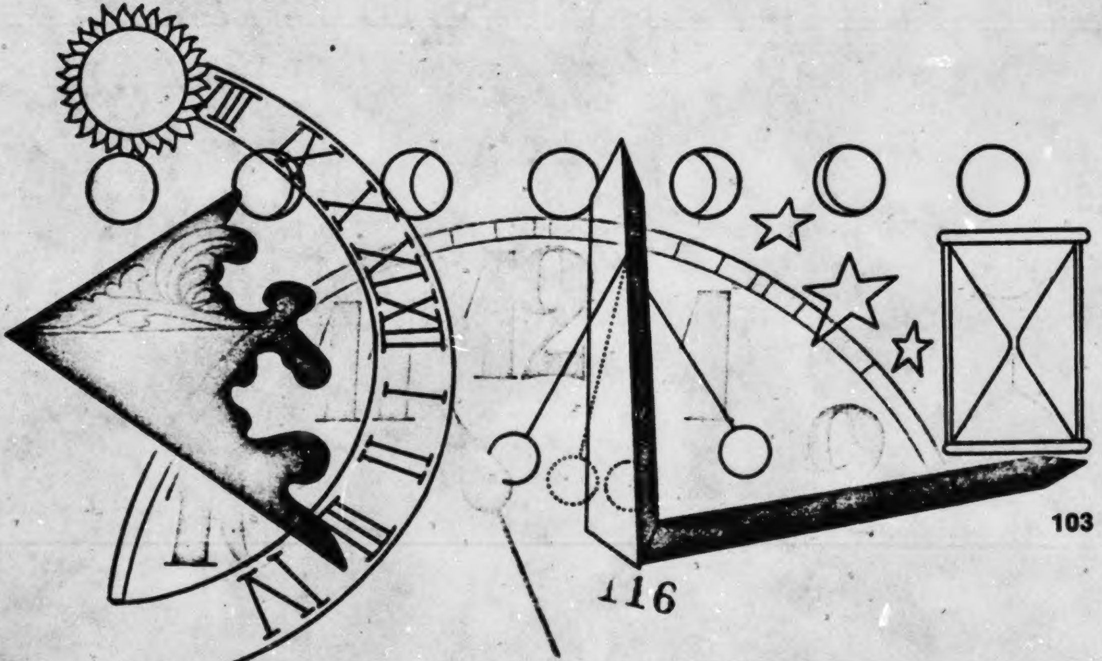
☐**4.** See if you can explain why Easter would have to occur within these dates in order to meet the council requirements.

Over the years the few minutes' difference between the time it takes the earth to go around the sun and the $365\frac{1}{4}$ days in the Julian calendar began to add up. In fact, by the year 1562 it added up to 10 full days. That year the first day of spring came on March 11 instead of March 21! This meant that Easter would be celebrated at a time before March 22. This violated the rules of the Church

Pope Gregory decided to find some way to change the calendar to make sure that Easter would be celebrated at the proper time. This decision led to the 10-day sleep mentioned at the beginning of this excursion. The pope decreed that the day following October 4, 1582, would be October 15. He also directed that, in the future, leap year would be omitted about once every 128 years. (This made the calendar year almost exactly the same length as the earth year.) The dropping of the specified leap years was designed to keep the first day of spring on the same date so that Easter would always be celebrated at the proper time.

THE GREGORIAN CALENDAR

The new calendar proclaimed by Pope Gregory became known as the Gregorian calendar. The Gregorian calendar set January 1 as the beginning of the year. Until then, the year had begun in some countries on December 25, in others on January 1, and in still others on March 25.



The Gregorian calendar was adopted immediately by countries with large Catholic populations. Protestant countries, and some countries in the Middle East, continued to use the Julian calendar. For example, the new calendar was not adopted in England until 1752. By this time, the English had to drop 11 days, not 10. Many Englishmen resented the change and held protest marches, crying "Give us back our 11 days." Most Middle Eastern countries didn't adopt the Gregorian calendar until 1923. These countries had to drop 13 days. The Chinese adopted the new calendar in 1912.

☐**5.** Can you explain why it was October 15 in Rome and only October 5 in London following Pope Gregory's decree?

The argument over which calendar to use has caused all sorts of trouble for people who study history. Historical dates depend upon what book you read. For example, George Washington was born either on February 22, 1732, or on February 11, 1731. The difference depends upon whether or not the writer dropped the 11 days and whether he considered the year as starting on January 1 or on March 1. In fact, some books list Washington's birthday as February $\frac{11}{22}$, $173\frac{1}{2}$.

The Pilgrims landed at Plymouth, Massachusetts, on December $\frac{11}{21}$, 1620. According to Governor William Bradford, they began building their first house on December 25, 1620. By the Gregorian calendar, however, this was January 4, 1621.

Changing the calendar has caused legal problems, too. Some landowners in England tried to collect rent on their property for the 11 days that were dropped from the calendar during 1752. The British Parliament had to pass a special act declaring that salaries, rents, and interest would not be collectable for the 11 lost days.

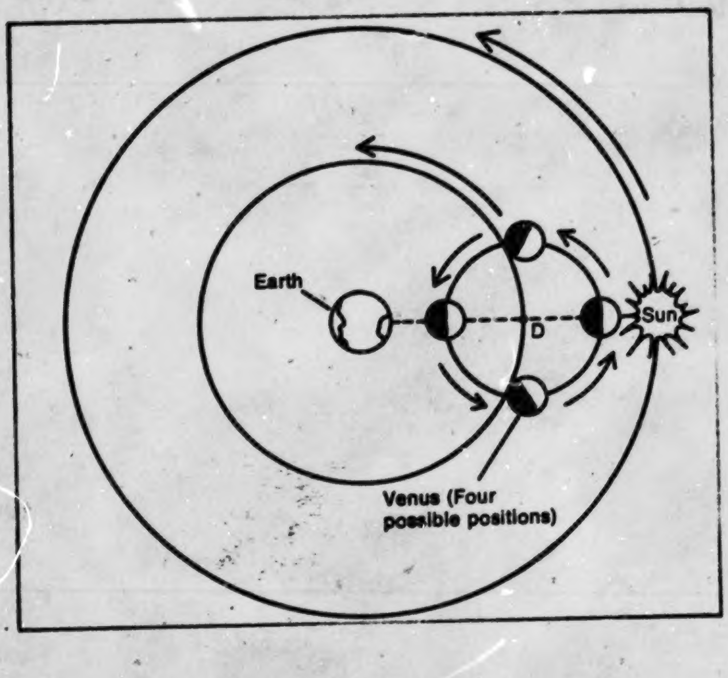
Matching Wits with Galileo

Excursion 6-2

According to the theory of Ptolemy, an ancient Greek astronomer, the earth is at the center of the solar system. In other words, the planets and the sun move around the earth (see Figure 1). Ptolemy's theory holds that Venus is closer to the earth than is the sun. Further, the theory holds that as Venus travels around the earth, it also moves in another circular path. Figure 1 shows this as a motion around point D.

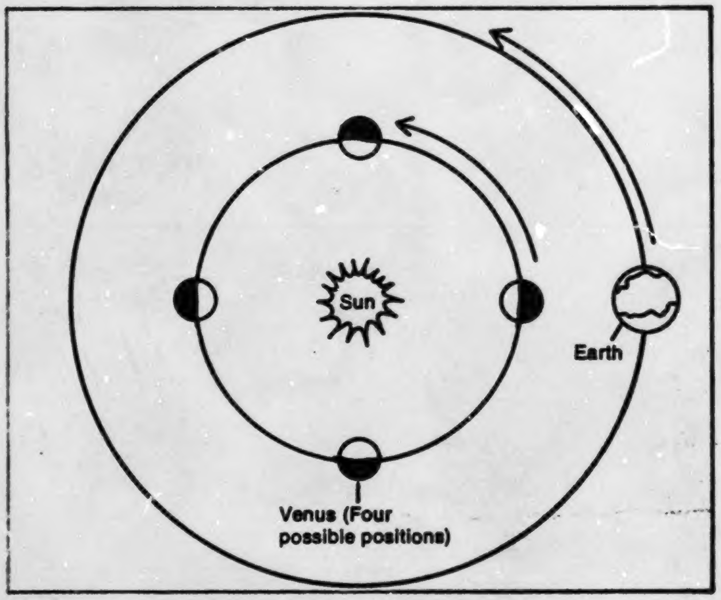
Ptolemy also believed Venus and the sun move in such a way that at any time a straight line can be drawn joining the earth, the sun, and point D.

Figure 1



Copernicus believed the sun is at the center of the solar system. He believed Venus and the earth (and the other planets as well) move around the sun (see Figure 2).

Figure 2



Galileo tried to decide which of the two theories was correct. With a telescope that he made, he observed Venus for two years. He observed some interesting changes in the appearance of the planet. What he saw is shown in Figure 3. He found that the shape of Venus changed, very much as the shape of our moon seems to change. Galileo realized that he had all the information he needed to decide definitely whether Ptolemy or Copernicus was right. You have all the information that you need, too. Match wits with Galileo. On the basis of the telescope evidence and Figures 1 and 2, tell which theory you support and why.

☐**1.** Which theory do you support?

☐**2.** What are your reasons for supporting the theory?

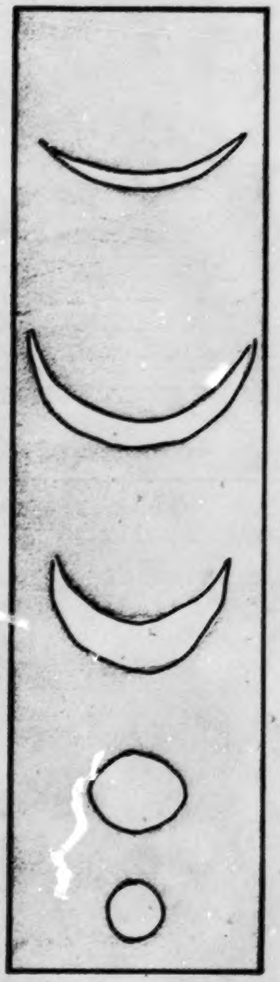


Figure 3

Power

Excursion 7-1

Suppose a house stands on a hill beside a river. The house catches on fire. Naturally, the owner would like to get water from the river and put out the fire. If he had no help, he could try to run back and forth with one or two buckets, carrying water to throw on the fire. But if the fire had much of a head start, he would lose his house.

If the owner had enough neighbors with buckets, they could form a double line, handing full buckets up and empty buckets down. Certainly more water could be carried to the house each minute this way. The chance of saving the house would be a great deal better.

Figure 1

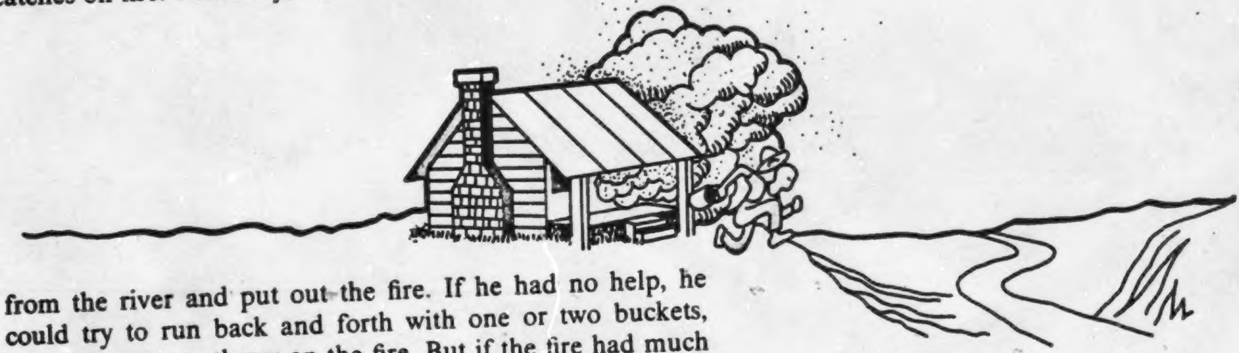
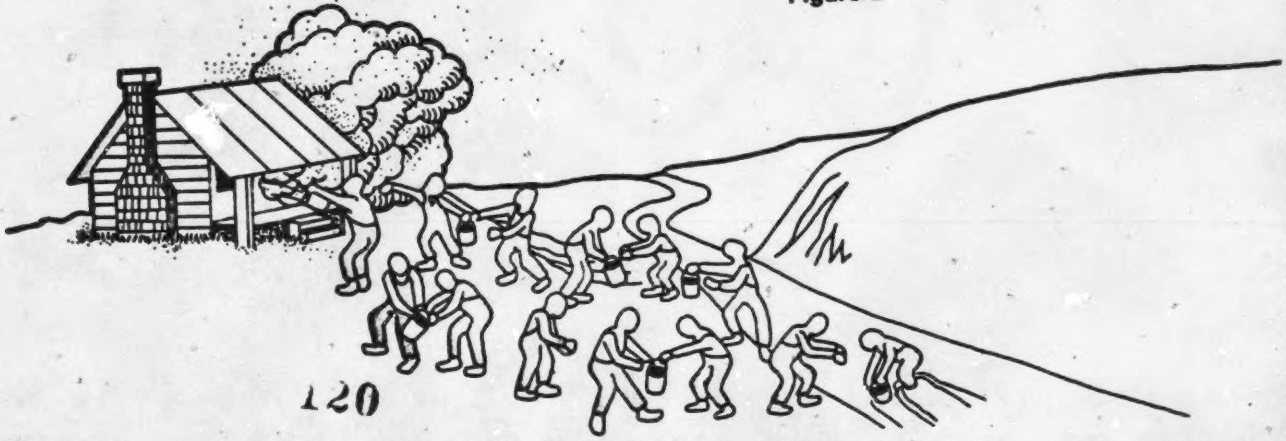
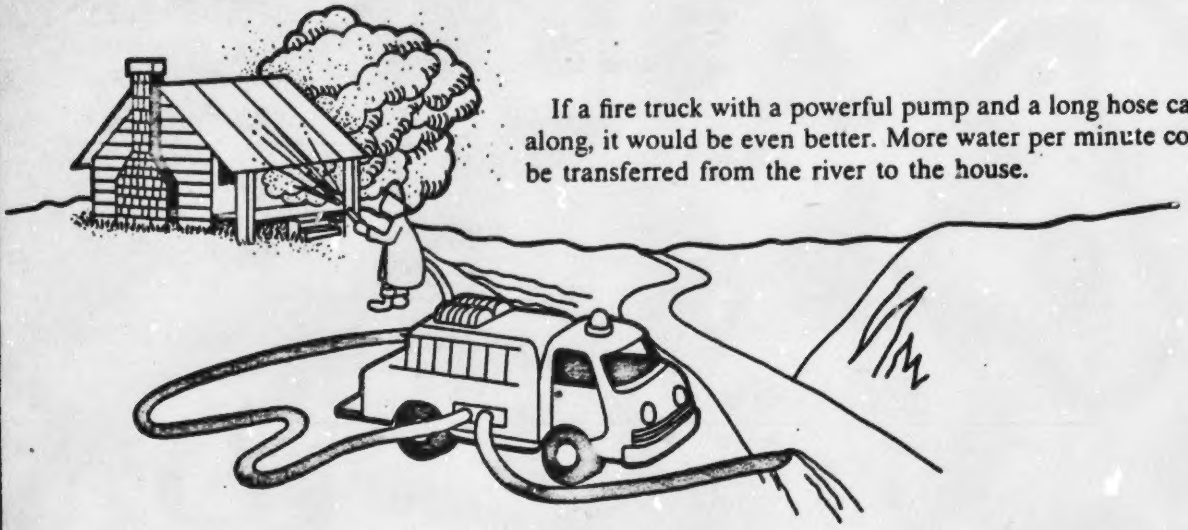


Figure 2





If a fire truck with a powerful pump and a long hose came along, it would be even better. More water per minute could be transferred from the river to the house.

Figure 3

What is the point of the story? Just this. Almost always, the time it takes to do a given amount of work is quite important. Given a long enough time, the owner by himself could have carried any amount of water from the river to the house. But after the house has burned down, the water does no good.

In the language of science, the *rate at which work can be done,* or the *rate at which energy can be transferred,* is almost always very important. The real difference between a man with a bucket and a fire truck with a pump is the rate at which each can do work.

Science has given a name to the rate of doing work, or the rate of energy transfer. The name is *power.*

The power of the sun is the amount of energy per second it sends out into space. This power can be measured in units called watts. If you had Level I of ISCS, you may recall the definition of a watt.

$$1 \text{ watt} = \frac{1 \text{ newton} \cdot \text{meter}}{\text{second}}$$

Remember, calculating the wattage of the sun means calculating the energy it produces per second.

Using Squares to Measure Distance

Excursion 7-2

In Chapter 7 you set out to measure the wattage of the sun. One way to do this is to use the process shown in Table 7-1. All that table calls for is doubling the distance and multiplying the wattage by four until the distance reaches 15,000,000,000,000 cm. But this is a rather slow process!

WHAT'S WATTS?

This problem could be solved more easily by using another approach. The key to the solution can be found in the relationship between the numbers in Table 1. These data show how the power of a light source must be increased to give the same amount of light as its distance from the object increases.

Table 1

Distance to Light Source	Power of Source (watts)
10 cm	50
20 cm	200
40 cm	800
80 cm	3200
93 million miles	?

Take a close look at the next table of data. It points out some important facts about the distance-power relationship.

Table 2

Distance to Source	Amount of Increase in Distance	Power of Source (watts)	Amount Power Source Must Increase to Give Same Light as a 50-watt Bulb at 50 cm
10 cm		50	
20 cm	2 times	200	4 times
40 cm	4 times	800	16 times
80 cm	8 times	3200	64 times
93 mil. miles	? times	?	? times

When the original distance of 10 cm is doubled, the wattage of the source must be made four times greater (200 watts = 4 × 50 watts). When the original distance is increased four times, the wattage must be made sixteen times greater (800 watts = 16 × 50 watts).

☐**1.** According to Table 2, how many times greater must the wattage be if the original distance is increased eight times?

Note the relationship between the times increase in the distance and the times increase in wattage.

Table 3

Distance Increase	Wattage Increase
2 times	4 times
4 times	16 times
8 times	64 times

The relationship between increase in distance and increase in wattage is called a "squared relationship." A number multiplied by itself is said to be "squared." The square of 2 is 2 × 2, or 4.

☐**2.** What is the square of 4?

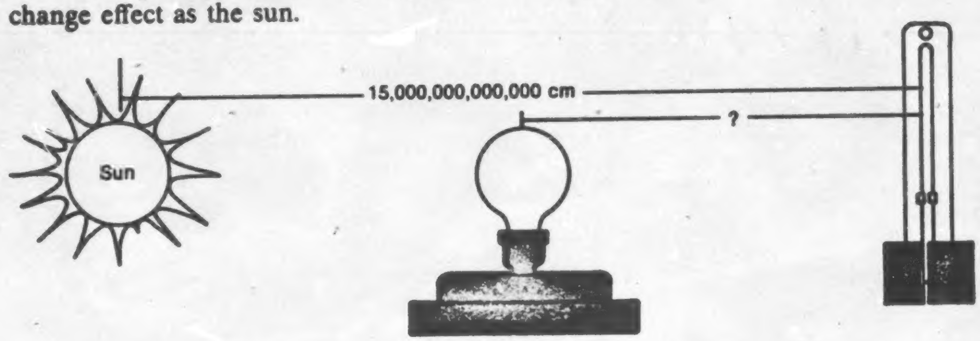
☐**3.** What is the square of 8?

Now how can all this be used to determine the power of the sun? You can calculate the number of times 10 cm must be increased to become 15,000,000,000,000 cm (the distance to the sun).

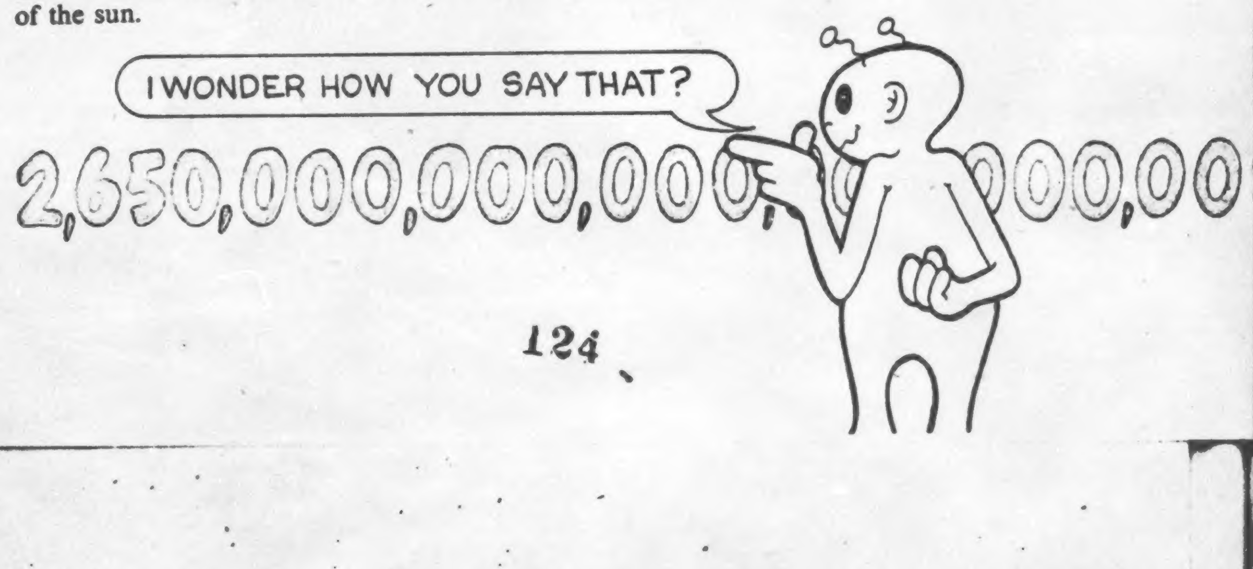
☐**4.** How many times will 10 cm go into 15,000,000,000,000 cm?

Now square your answer to question 4. Then multiply 50 watts by that number. The result will be the sun's power as calculated for the data given in Table 1.

However, the 10-cm distance measure in Table 1 was used to illustrate the method of calculating the sun's power. In Chapter 2, you actually compared the sun's effect with a 50-watt bulb. In question 2-18 of Chapter 2, you recorded a distance measure. This was the distance a 50-watt bulb had to be from your pyrheliometer to give the same temperature change effect as the sun.



☐**5.** Now use that distance measure to calculate the power of the sun.


I WONDER HOW YOU SAY THAT?
2,650,000,000,000 000,00

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